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A DISCUSSION OF HALPHEN'S METHOD  
FOR SECULAR PERTURBATIONS AND ITS  
APPLICATION TO THE DETERMINATION  
OF LONG RANGE EFFECTS IN  
THE MOTIONS OF CELESTIAL BODIES  
PART 2

by Arthur J. Smith, Jr.

Goddard Space Flight Center  
Greenbelt, Maryland

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JUNE 1964



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## **PART 2.**

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### **SUMMARY**

This paper discusses some applications of Halphen's method for determining the long range (secular) perturbations for planetary and cometary type orbits. This method of treating secular planetary effects has been suggested by Musen for the determination of the long range perturbations due to the moon for artificial satellite orbits. Two FORTRAN II computer programs incorporating this method are described and representative results are presented. The comparison of results obtained here with those obtained by applying other methods demonstrates the adequacy of this method for minor planets and appropriate artificial satellites. It shows also that considerable saving in computer time can be made in the study of artificial satellite orbits when the short period perturbations are not of interest by using a program based on Halphen's method rather than one based on the use of an unaveraged disturbing function. The program for artificial satellites is given.



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# A DISCUSSION OF HALPHEN'S METHOD FOR SECULAR PERTURBATIONS AND ITS APPLICATION TO THE DETERMINATION OF LONG RANGE EFFECTS IN THE MOTIONS OF CELESTIAL BODIES.

## PART 2.\*

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### INTRODUCTION

The motion of a minor planet or an artificial satellite with a planetary or cometary type orbit can be considered as simple Keplerian motion about the central body plus perturbations caused by the disturbing bodies. These perturbations, which generally necessitate numerical techniques, can be divided into two types: the short period perturbations with periods equal to the period of revolution of the satellite<sup>†</sup> or a fraction thereof, and the remainder, which are called long range (secular) perturbations.

The osculating ellipse can be specified at any instant by the five classical osculating orbital elements (e.g., Reference 1): the argument of pericenter  $\omega$ ; the longitude of the ascending node (called the right ascension of the ascending node if the reference plane is the equator instead of the ecliptic)  $\theta$ ; the inclination  $i$ ; the eccentricity  $e$ ; and the semi-major axis  $a$ . For theoretical investigations, the longitude of the pericenter  $\pi = \omega + \theta$  is of more interest than  $\omega$ . Primed symbols are associated with the disturbing body.

For studying the long range stability of the orbit of the satellite, the position of the satellite in its orbit is of no importance and is, therefore, not considered. Moreover, since the short period terms in the disturbing function can produce only very small long range perturbations in higher approximation through their mutual cross-action (Reference 2, p. 159), it is desirable to avoid consideration of them and to confine attention to the osculating elements associated with only the long range (secular) perturbations.

The disturbing function (the positive gradient of which is the perturbing "force") can be developed into a series of Legendre polynomials multiplied by appropriate factors. The expressions for the time derivatives of the osculating elements obtained by using this development of the disturbing

\*See Musen, P., "A Discussion of Halphen's Method for Secular Perturbations and Its Application to the Determination of Long Range Effects in the Motions of Celestial Bodies. Part 1," NASA Technical Report R-176, 1963.

†For brevity the word satellite will be used for either a minor planet or an artificial satellite or both.

function then can be averaged over the satellite orbit to remove the short period perturbations (Reference 3). The time derivatives of the osculating elements of the satellite orbit due to the long range effects remain. Here for the sake of brevity these will be called the *long range derivatives*. If the ratio  $a/a'$  of the semi-major axis of the satellite orbit to that of the orbit of the disturbing body is sufficiently small—there is normally no sharp commensurability of a low order in this case—the series development of the disturbing function will converge fast enough to permit an analytical treatment of the long range effects. For investigating the gravitational effect of the sun on the long range stability of orbits of earth satellites as well as for investigating the gravitational effect of the moon on the long range stability of orbits of close earth satellites, it is sufficient to retain, in the series development, the first term, which depends on the second Legendre polynomial. The second term is known as the parallactic term.

However, as  $a/a'$  increases, the orbit of the satellite becomes more of the planetary type—or of the cometary type if the eccentricity is large. The number of terms which must be retained in the series becomes progressively larger, and a different method for obtaining expressions from which the long range derivatives can be obtained becomes desirable.

Halphen's method (Reference 4) as stressed by Musen (Reference 5) has proved to be quite satisfactory for this purpose when there is no violation of the two restrictions inherent in the development of this method. The cross-action of short period terms is not taken into consideration; as a consequence the magnitude of the quantity  $\Delta a/a$  regulates the time interval of applicability of the theory, where  $\Delta a$  is the increment in  $a$  over an integration step. There are no secular perturbations of the first and second order in  $a$ ; therefore, the change in  $a$  cannot become large enough to have any appreciable effect on any of the other elements. The other restriction is that sharp commensurability is not handled. Except for these restrictions this method is valid for all  $a/a'$ ,  $e$ , and  $i$ . Naturally, the satellite can never enter the "activity sphere" of the disturbing body (Reference 1, p. 192).

The two divisors in the system of equations that is used for the long range derivatives are  $e$  and  $\sin i$ . To avoid the difficulties associated with these divisors being small it is possible to use a different system in which the elements  $\pi$ ,  $\theta$ ,  $i$ , and  $e$  are replaced by the quantities  $e \cos \pi$ ,  $e \sin \pi$ ,  $\sin i \cos \theta$ , and  $\sin i \sin \theta$ .

## COMPUTER PROGRAMS

There exist two IBM 709/7090 FORTRAN II programs for integrating the long range derivatives using the classical Runge-Kutta fourth-order method. One program is for minor planets under the gravitational effects of major planets. The other program is for artificial satellites of the earth under the gravitational effects of the moon, the sun, and the oblateness of the earth; this program, along with the necessary information for using it, is given in Appendix A.

The two programs have the following common features. The five classical orbital elements are considered the dependent variables with time as the independent variable. The initial values of these elements should be free of the influence of short period perturbations. Integration can proceed either forwards or backwards in time, with the number of integration steps being specified by an

input quantity. Since the size of the integration step is fixed by an input quantity, it is necessary to insure that the use of this step size provides dependable results during the course of the calculations. The two elements which can change with extreme rapidity due to small divisors are  $\omega$  and  $\theta$ . Therefore, as a control over the step size, another input quantity is used to limit the magnitude of the maximum allowable increment per integration step in these two elements. If this limit is exceeded, results for this integration step are not used, and calculations for this set of input data are terminated. However, since only a reduction in the size of the integration step is necessary for proceeding with these calculations, provision for doing so has been made by writing out the exact contents (with no binary-to-decimal conversion) of the storage locations for the independent and the five dependent variables. When at some later date these are used as a set of initial values, the storage locations containing them will be restored to precisely their former values.

If the calculations continue for the specified number of integration steps, the results obtained may indicate the desirability of proceeding further. Therefore, as before, the exact contents of the storage locations for the six variables are included in the output. It may or may not be desirable for the output also to include the values of the long range derivatives. If they are desired, they are available on a separate output tape specified by an input quantity; if this quantity equals zero, they are suppressed. Finally, the program is self-initializing so that each time that the program is used any number of sets of input data can follow each other.

Differences between the programs will now be considered. For a minor planet, the gravitational effects of as many of the major planets as desired may be included. The long range derivatives are obtained separately for the effect due to each of the disturbing planets using Halphen's method and then summed to obtain the total derivative (minus small cross-terms) for integrating. For the major planets (except Pluto) the secular variation of the elements (except  $a$ , which is taken as constant) and the great inequality of Jupiter and Saturn (References 6 and 7) are included. The unit of time for this program is the Julian century and of length, the astronomical unit;  $\pi$  is given in the output instead of  $\omega$ .

For an artificial satellite of the earth with a planetary or a cometary type orbit, the long range derivatives due to the gravitational effect of the moon are obtained again by using Halphen's method, and those due to the gravitational effect of the sun are obtained from a disturbing function expanded into a series of Legendre polynomials, with only the first term retained (Reference 3). It is necessary also to provide for the first order secular perturbations in the argument of perigee and in the right ascension of the ascending node which are due to the oblateness of the earth. For planetary or cometary type orbits the effect of oblateness is only an additive one, and the appropriate expressions are

$$\frac{d\omega}{dt} = \frac{Jn(4 - 5 \sin^2 i)/2}{[(1 - e^2)a/R_E]^2}$$

and

$$\frac{d\theta}{dt} = \frac{-Jn \cos i}{[(1 - e^2)a/R_E]^2}$$

To obtain the total derivative for any element the derivatives of this element due to the various effects which are to be considered are summed. For both the moon and the sun, expressions for the secular effects in the elements are included (Reference 7, p. 98 and 107). The effect of the precession from 1950.0 to the mean equinox of date is neglected, because it does not contribute to the results more than a few tenths of a degree after several tens of years.

When the perigee distance,  $q = a(1 - e)$ , becomes less than some amount (which depends on the physical characteristics of the satellite), the effect of atmospheric drag can no longer be ignored. Since some other method of calculating is necessary for proceeding past this point, the program compares the perigee distance with an input quantity after each integration step in order to terminate, if necessary, the calculations for this set of data before the specified number of integration steps. The exact contents of the storage locations for the six variables are written out in this case also. The unit of time for this program is the day and of length, the radius of the earth,  $R_E$ .

The running time on the IBM 7090 for either program is about 1 second per integration step per disturbing body when 24 intervals are used to perform the process of averaging over the orbit of the satellite.

## REPRESENTATIVE RESULTS AND COMPARISONS

The orbital elements for five sample minor planets (Reference 8)\* under the secular gravitational influence of Jupiter and Saturn were obtained by integrating both forwards and backwards in time for one hundred integration steps of one century each using twenty-four intervals for averaging over the orbit. The numerical results are presented in the form of both graphs (Appendix B, Figures B1-B15) and tables (Appendix C). The reference does not indicate the exact nature of the starting elements, but it is the general behavior of the orbit of the minor planet with time that is of interest, and this is not significantly influenced by the type of starting elements. Previously, considerable analytical work was necessary to obtain expressions for the derivatives of the orbital elements, which were then integrated analytically, if at all possible, with considerable labor. But with the advent of high-speed computing equipment, it has become possible to do much of the work involved numerically.

The values of the elements together with the corresponding epochs for the five sample minor planets are as follows:

<u>MINOR PLANET</u>	<u>EPOCH</u>	<u><math>\pi</math></u>	<u><math>\theta</math></u>	<u>i</u>	<u><math>\phi</math></u>	<u>a (au)</u>
(1) CERES	1957 Jun 11.0	152.367	80.514	10.607	4.353	2.7675
(2) PALLAS	1957 Jun 11.0	122.734	172.975	34.798	13.534	2.7718
(30) URANIA	1942 Dec 11.0	33.405	309.078	2.103	7.295 <sup>†</sup>	2.3657
(1036) GANYMEDE	1950 Jun 28.0	347.337	216.262	26.298	32.854	2.6584
(1373) 1935 QN	1941 Jan 6.0	37.119	298.068	38.902	18.759	3.4111

\*The information in part a of Reference 8 for the 1646 minor planets (864 = 1078) has been put on punched cards with asterisks, spaces, decimal points, and references omitted. Seventy-two columns were used, with 14 being exactly sufficient for the names.

<sup>†</sup>This value was in an errata.

Note that  $\phi = \text{Arcsin}(e)$  is given in the reference for the minor planets. In the output  $e$  is expressed in degrees by multiplying it by  $180/\pi$ .

Examination of the graphs of even the small number of cases presented herein shows that the variation of the elements can be very similar in one respect and quite different in another for two minor planets. Several points might be mentioned. From results covering intervals of 200 centuries the elements for minor planets (2), (1036), and (1373) appear to have relatively short periods—about 150 centuries for (2), about 82 for (1036), and about 116 for (1373)—while the periods of (1) and (30) appear to be too long to estimate from the present results. The eccentricity (in degrees) and inclination over intervals of 200 centuries for (1) and (30) are essentially restricted to ranges of less than  $3^\circ$ . For minor planets (2) and (1373) the ranges for the eccentricity (about  $16^\circ$  and  $13^\circ$  respectively) are larger than the ranges for the inclination (about  $10^\circ$ ), while for (1036) the opposite situation is found (about  $12^\circ$  for  $e$  and about  $15^\circ$  for  $i$ ).

The mean motion (time rate of change) of  $\theta$  for all five minor planets is negative and is about  $-1.32^\circ$  per century for (2) and (30), about  $-1.56^\circ$  per century for (1), and about  $-1.88^\circ$  per century for (1036) and (1373). The mean motion of  $\pi$ , the longitude of perihelion, takes on both positive and negative values; for minor planet (1) the value is about  $1.62^\circ$  per century, for (30) about  $0.88^\circ$  per century, and for (1036) about  $0.35^\circ$  per century. The mean motion for (2) appears to be about  $-0.1^\circ$  per century in the interval under consideration, while for (1373) the value is about  $-1.88^\circ$  per century. One other point is to be noted. For minor planet (1373) the mean motion of  $\omega$  ( $=\pi - \theta$ ), the argument of perihelion, is essentially zero; therefore the value of  $\omega$  is confined to the interval determined by the oscillations in  $\pi$  and  $\theta$ ; i.e., the motion of  $\omega$  is that of libration. This is in agreement with analytical work done by Kozai (Reference 9),\* who found that the motion of  $\omega$  for (1373) was that of libration, while that for (1036) was not.

An attempt was made to compare for (1036) Ganymede results using this method with results obtained by Putilin (References 10 and 11). It is seen from Table 1 that the values of the derivatives of the elements obtained for the effect of Jupiter agree quite well, while those for the effect of Saturn are in poor agreement with little uniformity. It therefore appears that there may be a computational error in Reference 11. The original calculations of Goriachev (Reference 12) for (1) Ceres with Jupiter and Saturn taken into consideration were also compared with results from the computer program. From Table 1 it can be seen that for both disturbing bodies there is quite satisfactory agreement, although the agreement in the perturbations caused by Jupiter is found to be noticeably better than in the perturbations caused by Saturn.

Results obtained with the use of starting elements for a cometary type orbit are shown in Appendix B Figures B16-B18 and in the tables. Elements for Encke's comet were used, and as in the case of the minor planets, Jupiter and Saturn were the disturbing bodies with the integration continued for 100 centuries in both directions using a one century integration step. Twenty-four intervals were used for averaging over the orbit of the comet. The results obtained here agree qualitatively with those of Whipple (Reference 13) and Brouwer (Reference 14) in that the period

\*Kozai gives the upper limit of the inclination of (1036) as  $48^\circ$ . There appears to be a computational error at this point, with the correct value being approximately  $35^\circ$ .

Table 1

The Results for (1036) Ganymede and (1) Ceres of this Computation Compared with the Results of Putilin and Goriachev, Respectively. (All values are in seconds of arc per Julian year).

Derivative of the element	(1036) Ganymede				(1) Ceres			
	Jupiter		Saturn		Jupiter		Saturn	
	Putilin	This Work	Putilin	This Work	Goriachev	This Work	Goriachev	This Work
$\frac{d\pi}{dt}$	-4.30382	-4.30341	+0.19058	+0.24596	+55.90872	+55.90846	+1.29011	+1.31546
$\frac{d\theta}{dt}$	-77.65939	-77.65919	-2.82690	-2.96219	-52.18351	-52.18315	-1.41103	-1.41002
$\frac{di}{dt}$	+21.36532	+21.36513	+0.66037	+0.72459	-0.57724	-0.57724	-0.04072	-0.04096
$\frac{de}{dt}$					-0.67520	-0.67526	-0.02238	-0.02500
$\frac{d\phi}{dt}$	-15.98070	-15.98064	-0.42288	-0.46238				
$\frac{dL}{dt}$ *	-29.11310	-29.11312	-1.69845	-1.85503	-56.05317	-56.05280	-2.12460	-2.12200

\* $L = \pi + i$  = mean longitude;  $i$  = mean anomaly.

of the variation of the inclination is one half of the period of a complete revolution of  $\omega$ . The main difference is in the size of the period of variation. Whipple found it to be about 29.4 centuries, while Brouwer, using different starting data, found it to be about 34.1 centuries in his first approximation (which corresponded to Whipple's work) and about 36.2 in his third approximation. Brouwer mentioned the possibility of including the effect of the eccentricity of Jupiter but did not determine the resultant period. The period obtained here is about 45.6 centuries without making the simplifying assumption of a restricted three body problem (both Jupiter and Saturn are included). Both Whipple and Brouwer used the constant value of 0.847 for the eccentricity; from Figure B18 it is seen that when the oscillations of about 0.005 (= 0.3°) amplitude (and period of about 45.6 centuries) are ignored, the eccentricity does indeed change in 200 centuries by only 0.017 (= 1°). The elements used here were  $\omega = 185.2^\circ$ ,  $\theta = 334.7^\circ$ ,  $i = 12.4^\circ$ ,  $e = 0.847$ ,  $q = a(1 - e) = 0.338$  au (Reference 15, p. 37); the epoch was arbitrarily taken as 1900.0 (the epoch of Reference 6). References 13 and 14 used elements at the epoch 1855,  $\omega' = 188.0^\circ$ ,  $\theta' = 331.0^\circ$ ,  $i' = 13.9^\circ$ ,  $e = 0.847$ , and  $a = 2.217$  au, where  $\omega'$ ,  $\theta'$ , and  $i'$  are referred to Jupiter's orbital plane.

The Interplanetary Monitoring Probe (IMP), now under development, is especially interesting because of its cometary type orbit due to its large semi-major axis (about 22.8 earth radii) and its large initial eccentricity (about 0.955). The large change in inclination that it experiences is also of interest. The gravitational effects acting on IMP have been extensively studied (References 16, 17, and 18) by B. E. Shute, who suggested an illustrative set of initial osculating orbital elements.

One aspect of the work done by Shute was to extend to three years the computation of osculating elements, using a program based on an unaveraged disturbing function (Reference 19), due solely to the gravitational effect of the moon to obtain a check on the adequacy of Halphen's method for handling this large semi-major axis and this large initial eccentricity.<sup>†</sup> The initial osculating

<sup>†</sup>The IBM 7090 time used was approximately half an hour per year in orbit.

elements used were  $\omega = 153^\circ 500000$ ,  $\theta = 165^\circ 000000$ ,  $i = 33^\circ 000000$ ,  $e = 0.95466817$ ,  $a = 22.820827$  earth radii, and mean anomaly =  $0^\circ 000000$  at the epoch, 1961 Jan 1.0. Computed osculating elements were written out at one day intervals; those for the first 200 days after the epoch and for the interval from 950 to 1050 days (i.e., near the end of 3 years) are shown in Figures 1-5.

It is seen most clearly from the graph of the osculating semi-major axis (Figure 5) that the main effect of the terms depending upon the mean anomalies of both the satellite and the moon is a small oscillation with a period of about 108 days due to the ratio of nearly 4 to 1 of the mean motions; the osculating semi-major axis is restricted essentially to the interval between 22.68 and 22.88 ( $= 1.009 \times 22.68$ ) earth radii. It is seen also that the osculating angles can shift or change markedly during the first revolution of the satellite.

There is the question of how to obtain starting values for use with Halphen's method from these osculating elements. One procedure that suggested itself was to average the osculating elements over some interval. With the assumption that osculating elements for several periods after the epoch were available, various possible intervals were examined using the following procedure. Since the osculating semi-major axis, and therefore the period  $P$ , was not a constant, the expression

$$\bar{P} = \frac{1}{T_f - T_0} \int_{T_0}^{T_f} P(t) dt$$

was evaluated by applying the trapezoidal rule and taking  $T_f$  about 32 days after  $T_0$ , the time at the epoch; the result was  $\bar{P} = 6.36$  days. Then the mean values of the osculating elements associated with the midpoint of  $\bar{P}_i$ , the  $i$ th mean period ( $i$  from 1 to 5), were obtained by evaluating the expression

$$\bar{\alpha}_i = \int_{T_0 + (i-1)\bar{P}}^{T_0 + i\bar{P}} \alpha(t) dt$$

by using the trapezoidal rule, where  $\alpha$  represents each of the osculating elements. The results are shown in Table 2, along with various groupings of the mean periods into intervals. (The number of digits retained in these mean values of the osculating elements is two less than in the osculating elements.)

The sets of elements in Table 2 were used as starting elements for integrating backwards to  $T_0$ , the beginning of the first mean period (where it is recognized that in many of the cases the integration step was inappropriately short). The results are in Table 3. It is seen from this table that for all elements except the eccentricity the greatest differences occur when the results from the intervals corresponding to  $\bar{P}_1$  and  $\bar{P}_2$  are compared. When results from these two intervals are not considered, the range in values of  $\bar{\omega}(T_0)$  is about 0.63, in  $\bar{\theta}(T_0)$  about 0.77, in  $\bar{i}(T_0)$  about 0.98, in  $\bar{e}(T_0)$  about 0.0027 ( $= 0.0028 \times 0.9547$ ), and in  $\bar{a}(T_0)$  about 0.033 ( $= 0.0014 \times 22.821$ ) earth radii. Thus it

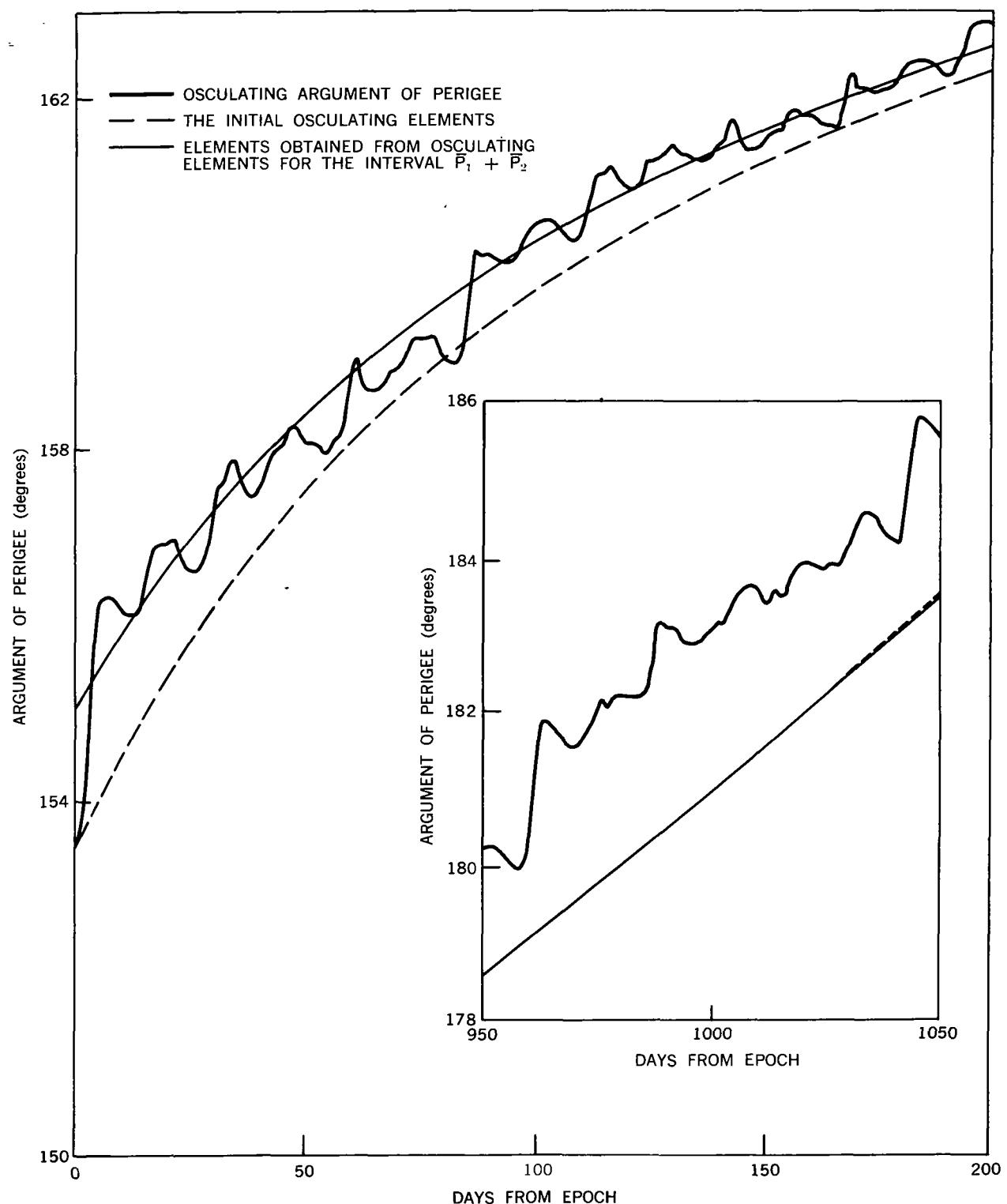


Figure 1—Comparison of Osculating  $\omega$  for an IMP-like orbit (moon only) with  $\omega$ 's obtained using Halphen's method.

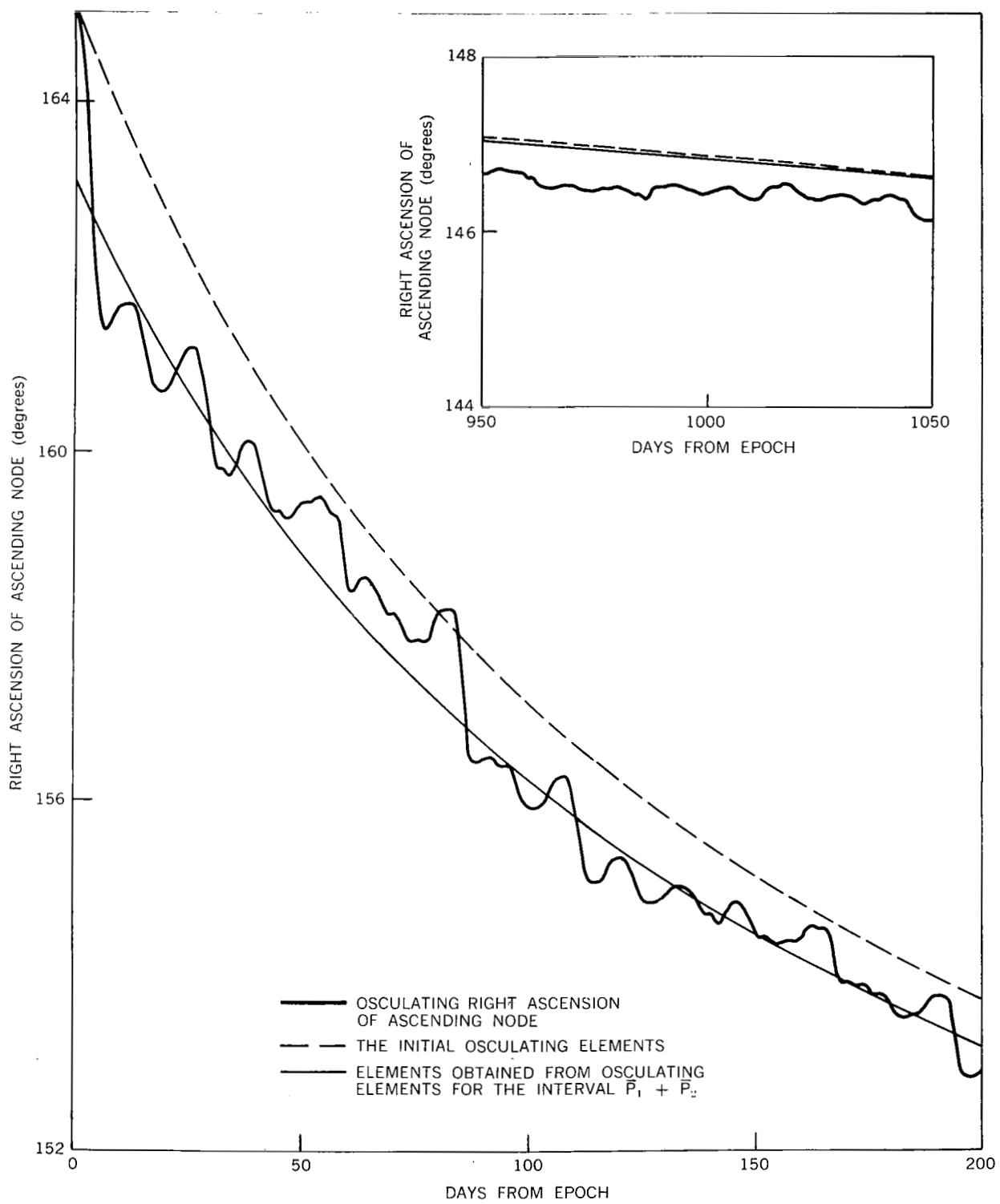


Figure 2—Comparison of Osculating  $\theta$  for an IMP-like orbit (moon only)  
with  $\theta$ 's obtained using Halphen's method.

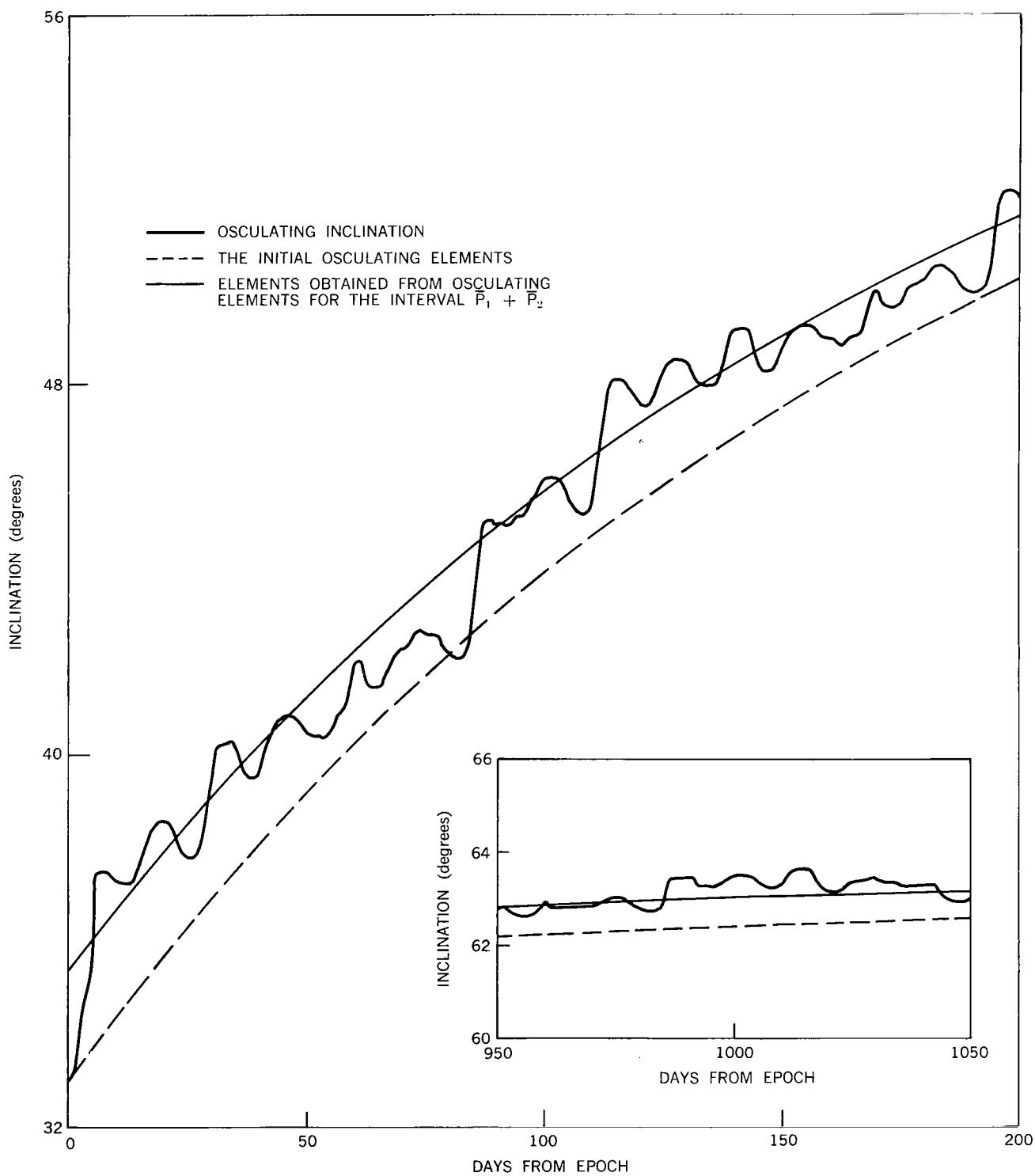


Figure 3—Comparison of Osculating  $i$  for an IMP-like orbit (moon only) with  $i$ 's obtained using Halphen's method.

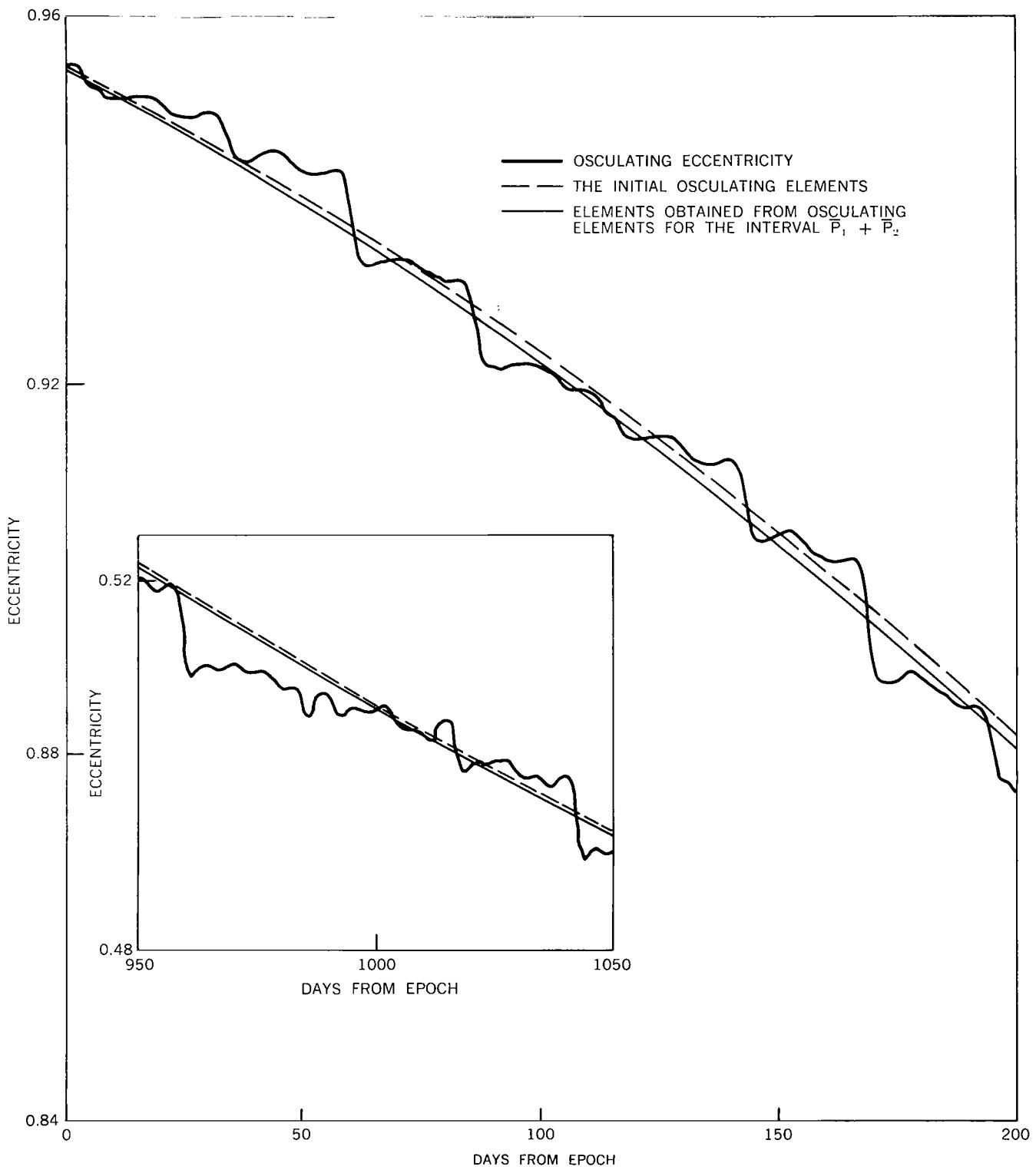


Figure 4—Comparison of Osculating  $e$  for an IMP-like orbit (moon only)  
with  $e$ 's obtained using Halphen's method.

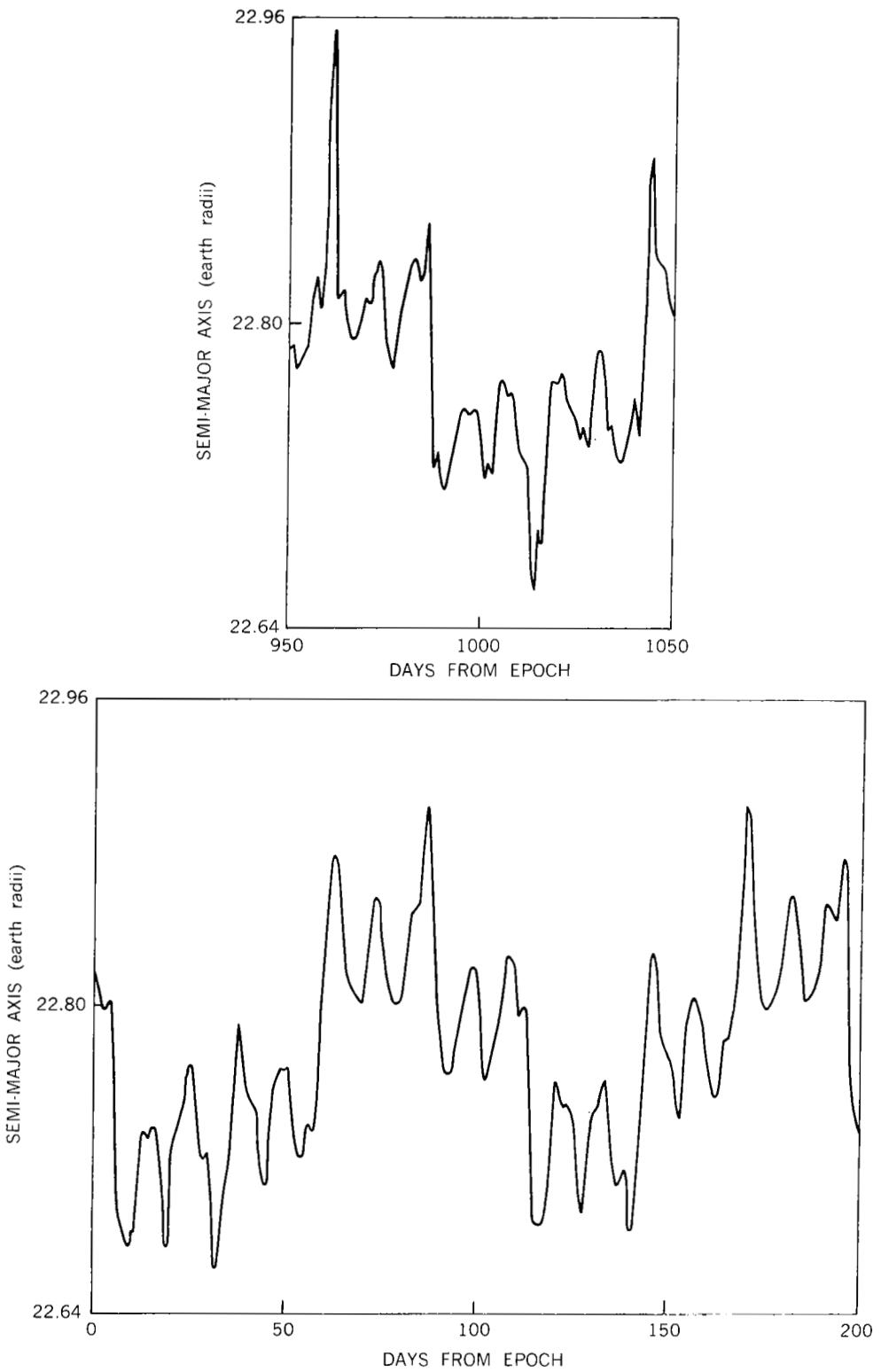


Figure 5—Osculating  $a$  for an IMP-like Orbit (moon only).

Table 2

Mean Values of Osculating Elements at Middle of Interval for Various Intervals.

Mean Periods $\bar{P}_i$ Comprising Interval	t, Time at Middle of Interval (days)	$\bar{\omega}(t)$ (degrees)	$\bar{\theta}(t)$ (degrees)	$\bar{i}(t)$ (degrees)	$\bar{e}(t)$	$\bar{a}(t)$ ( $R_E$ )
1	3.18	155.0085	163.1121	35.1019	0.954069	22.7888
2	9.54	156.2252	161.5993	37.3561	0.951243	22.6901
3	15.90	156.6130	161.0651	37.9700	0.951165	22.7236
4	22.26	156.8199	160.9328	38.2046	0.949896	22.7357
5	28.62	157.0641	160.5136	38.7410	0.949251	22.7263
1 + 2	6.36	155.6168	162.3557	36.2290	0.952656	22.7395
2 + 3	12.72	156.4191	161.3322	37.6630	0.951204	22.7068
3 + 4	19.08	156.7164	160.9989	38.0873	0.950530	22.7296
4 + 5	25.44	156.9420	160.7232	38.4728	0.949573	22.7310
1 + 2 + 3	9.54	155.9489	161.9255	36.8093	0.952159	22.7342
2 + 3 + 4	15.90	156.5527	161.1990	37.8435	0.950768	22.7165
3 + 4 + 5	22.26	156.8323	160.8371	38.3052	0.950104	22.7285
1 + 2 + 3 + 4	12.72	156.1666	161.6773	37.1581	0.951593	22.7346
2 + 3 + 4 + 5	19.08	156.6806	161.0277	38.0679	0.950389	22.7189
1 + 2 + 3 + 4 + 5	15.90	156.3461	161.4446	37.4747	0.951125	22.7329

Table 3

Mean Values of Osculating Elements at  $T_0$  for Various Intervals.

Mean Periods $\bar{P}_i$ Comprising Interval	$\bar{\omega}(T_0) = 153^\circ 5000$	$\bar{\theta}(T_0) = 165^\circ 0000$	$\bar{i}(T_0) = 33^\circ 0000$	$\bar{e}(T_0) = 0.954668$	$\bar{a}(T_0) = 22.8208$ ( $R_E$ )
2	1.9609	-2.4508	3.1357	-0.000815	-0.1307
2 + 3	1.9027	-2.4029	3.0283	+0.000012	-0.1140
3	1.8457	-2.3556	2.9170	+0.000838	-0.0972
2 + 3 + 4	1.7796	-2.2173	2.7974	+0.000447	-0.1043
3 + 4	1.6888	-2.1000	2.6244	+0.001077	-0.0912
2 + 3 + 4 + 5	1.6533	-2.0720	2.6112	+0.000936	-0.1019
1 + 2 + 3	1.6401	-2.0755	2.5580	+0.000064	-0.0866
1 + 2 + 3 + 4	1.6021	-2.0058	2.4966	+0.000369	-0.0862
1 + 2	1.5610	-1.9608	2.3882	-0.000307	-0.0813
3 + 4 + 5	1.5506	-1.9452	2.4324	+0.001518	-0.0923
1 + 2 + 3 + 4 + 5	1.5272	-1.9217	2.4031	+0.000769	-0.0879
4	1.5295	-1.8422	2.3318	+0.001319	-0.0851
4 + 5	1.4012	-1.7383	2.1902	+0.001860	-0.0898
5	1.2742	-1.6355	2.0486	+0.002400	-0.0945
1	1.2058	-1.5195	1.6676	+0.000236	-0.0320

does not make a great deal of difference how the osculating elements are averaged; probably the results from the interval  $\bar{P}_1 + \bar{P}_2$  (composed of the first two mean periods) have as much to recommend themselves as any others.

Runs were made with the program described in this paper by using both the initial osculating elements and the elements from Table 3 for the interval  $\bar{P}_1 + \bar{P}_2$ ; the first pair of runs included only the effect of the moon, a second pair the effects of the moon and the oblateness of the earth, and a third pair included both of these effects plus the effect of the sun. Results of these three pairs of runs are presented in Figures 6-9, and the results from the first pair of runs are repeated in Figures 1-4.

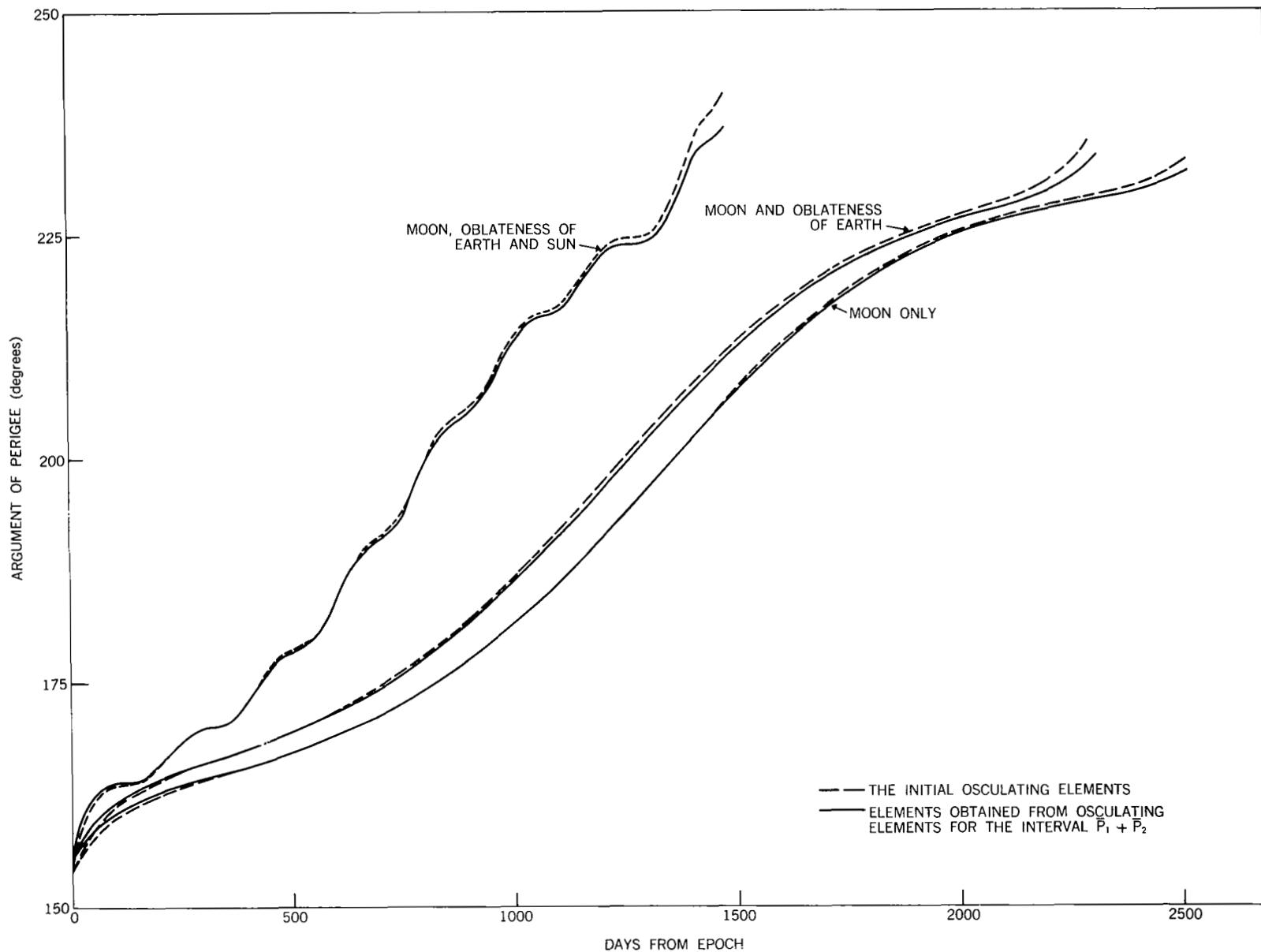


Figure 6—Effect of Starting Elements and Various Gravitational Effects on  $\omega$  for an IMP-like Orbit.

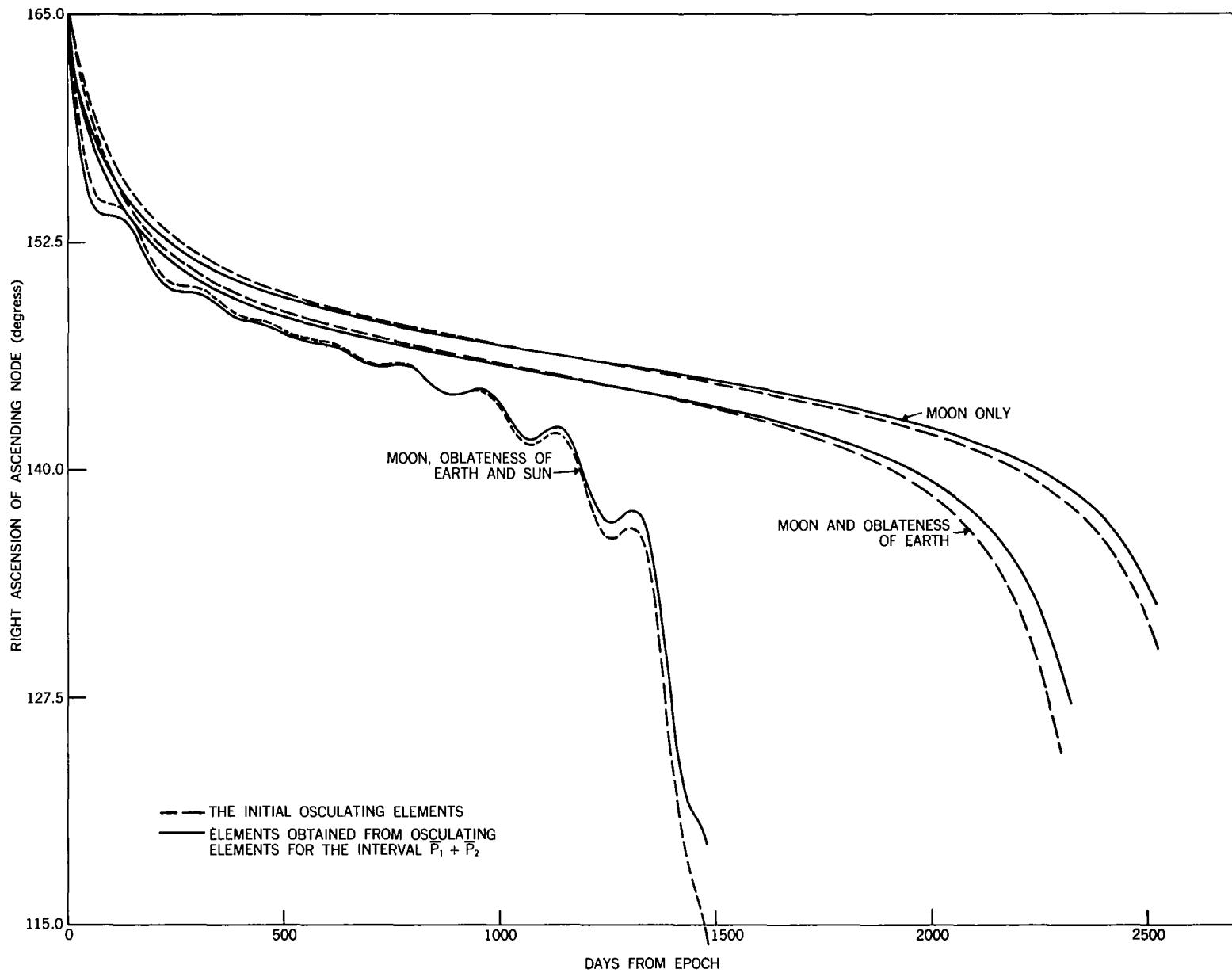


Figure 7—Effect of Starting Elements and Various Gravitational Effects on  $\theta$  for an IMP-like Orbit.

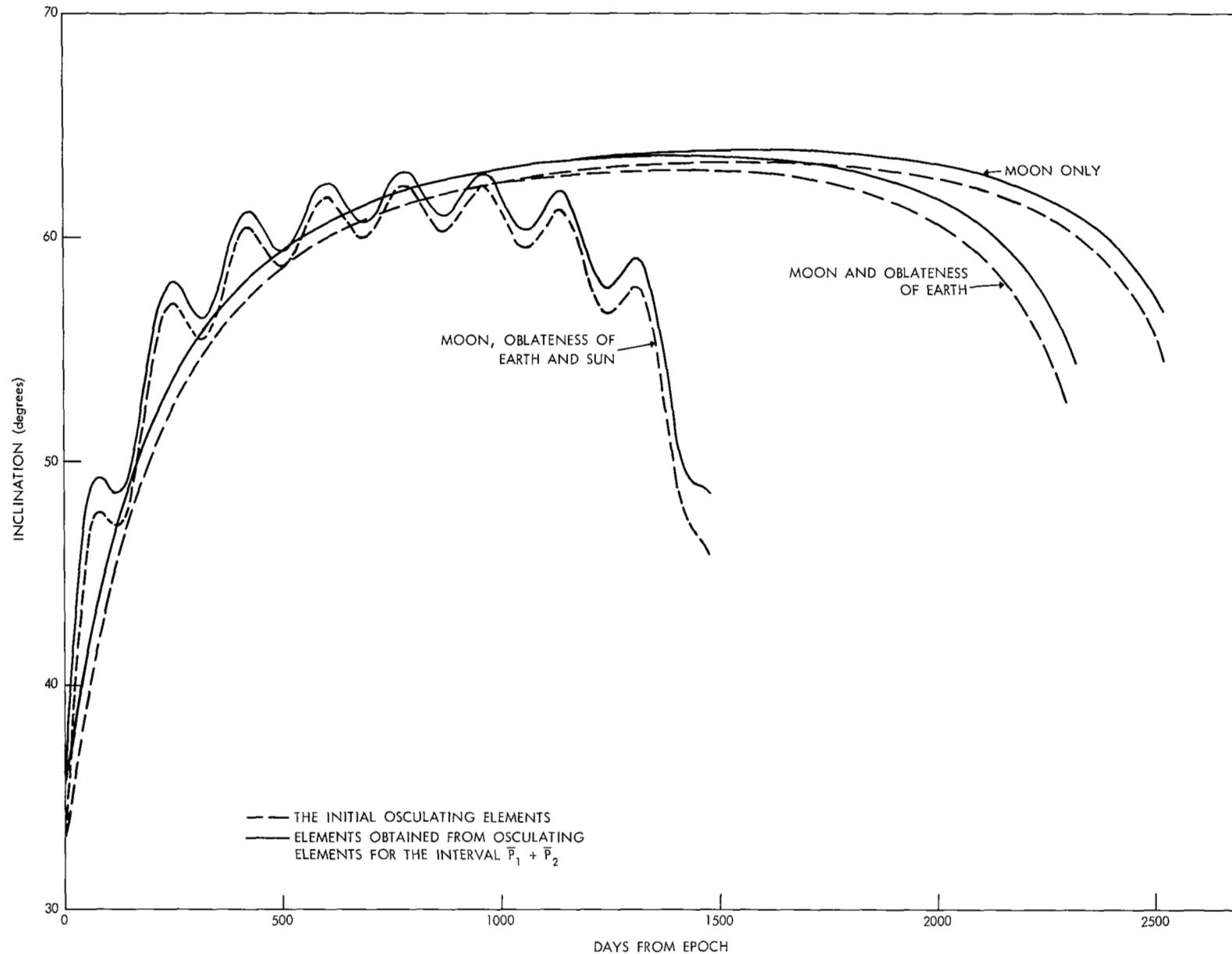


Figure 8—Effect of Starting Elements and Various Gravitational Effects on  $i$  for an IMP-like Orbit.

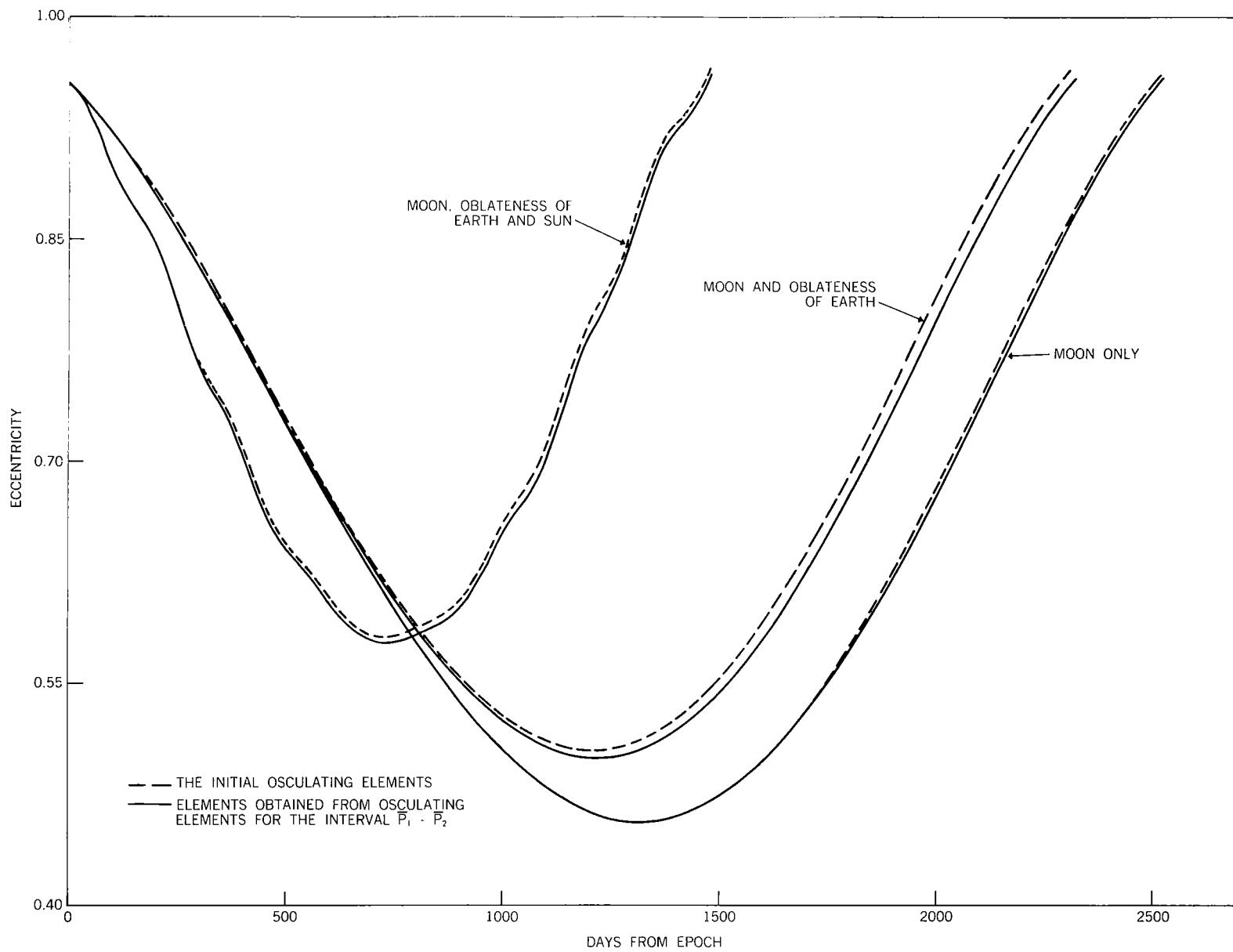


Figure 9—Effect of Starting Elements and Various Gravitational Effects on  $e$  for an IMP-like Orbit.

The results from the first pair of runs serve also as a demonstration of the stability of Halphen's method when small changes are made in the input. Several other runs were made by using various sets of elements obtained by averaging the osculating elements more or less by inspection, and quite similar results were still obtained; these results demonstrate further the stability of the method. All runs used an integration step of 20 days and terminated when the perigee distance became less than one earth radius. Twenty-four intervals were used for averaging over the orbit of the satellite.

These graphs indicate the effect of employing the above procedure to obtain starting elements for use with Halphen's method (and which are suitable for use with the other gravitational perturbations) instead of using simply the starting osculating elements. In many cases this difference may be of little consequence, but when osculating elements are available for some reasonable interval of time after the epoch, the above procedure might be used. One reason for obtaining the osculating elements is that the initial eccentricity might be large enough so that a small increase due to short period lunar perturbations, when the satellite is near perigee, is sufficient to cause it to enter too deeply into the atmosphere.

## CONCLUSION

As part of the overall problem of the stability of the solar system, an untold amount of work remains to be done on the problem of the minor planets. Some necessarily must be done analytically, but a great deal can feasibly be performed numerically with high-speed computing equipment. Where there is no sharp commensurability between the motion of the minor planet and a major planet, Halphen's method is admirably suited in both accuracy and speed for doing extensive work on the secular perturbations of the minor planets.

The results for IMP, which is rather an extreme case, show again that for the purpose for which Halphen's method is intended, i.e., in this case that of determining the effect of lunar perturbations in the overall history of a planetary or cometary type satellite orbit, it is entirely adequate even when large eccentricities and inclinations (and large changes) are involved. It also uses far less computer time than any method based on the use of an unaveraged disturbing function.

## ACKNOWLEDGMENT

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## Appendix A

### **FORTRAN II Program for the Long Range Gravitational Effects in the Motion of Artificial Satellites**

#### **Introduction**

The classical Runge-Kutta fourth-order method is used for integrating the long range derivatives of the five classical orbital elements due to the gravitational effects of the moon, the sun, and the oblateness of the earth.\* Any combination of these effects can be included, and integration can proceed either forwards or backwards in time; the number of integration steps is specified by an input quantity. Since inspection of the output for a set of input data may indicate the desirability of extending the calculations for this set of input data, provision has been made in the following way for doing so. After the routine output of the independent and the five dependent variables at the end of the last integration step is given using E-type conversion,<sup>†</sup> the contents of the storage locations for these six variables are also given using the O-type conversion (i.e., 12 octal digits per storage location). Then the use at some later date of this O-type output as a set of "initial" values of the six variables will restore the appropriate storage locations to precisely their former values, and any effects due to binary-to-decimal and decimal-to-binary conversion will be avoided.

The restrictions on the two quantities  $e$  and  $\sin i$  are  $0 < e < 1$  and  $0 < \sin i \leq 1$ . Since they are also divisors, they in turn can limit the size of the integration step, since they can become small enough so that  $\omega$  and  $\theta$  change too rapidly to be calculated with sufficient accuracy with the integration step used. This event has been provided for by using an input quantity to limit the magnitude of the maximum allowable increment in  $\omega$  or  $\theta$  per integration step. If this limit is exceeded, a message is given and the increments in the variables corresponding to this integration step are not used. The contents (at the end of the last valid integration step) of the storage locations for the six variables again are given using the O-type conversion. As before, this O-type output will allow the necessary storage locations to be restored if calculations are to be continued at a later date with a smaller integration step.

Provision has also been made for specifying the minimum allowable value of the perigee distance,  $q = a(1 - e)$ , by means of an input quantity. After the values of the variables at the end of each integration step are given, the perigee distance is compared with the allowable minimum; if it has gone below, a message indicates this, and for completeness the O-type output is again given.

The program incorporates the routine tests for floating-point overflow and divide check and for negative arguments of the square root function. If any of these should occur, or if  $e$  or  $\sin i$  should

\*The appropriate expressions for the sun (taken from Reference A1) are on p. 24-25, and those for the oblateness are on p. 3. Primed symbols are associated with the disturbing body.

<sup>†</sup>This can readily be changed to F-Type conversion; see comment card above statement 46 in the main program.

go out of range, or if an incorrect value of any of the integer input quantities should be present, the calculations for this set of input data are terminated, and a message is given to indicate the difficulty causing the termination. Since the integration scheme requires the derivatives to be evaluated four times per integration step, this message includes an integer N with values from 1 to 4 to indicate which evaluation of the derivatives was in process when the difficulty was encountered. (Note that output of results occurs between  $N = 1$  and  $N = 2$ ). Since it is not always easy to determine the cause of difficulty (especially if unexpected), statements 152 in the main program and 40 in the subroutine are included, which are never reached unless a message is first given indicating that difficulty has been encountered. If execution of the program is under IBM 709/7090 FORTRAN Monitor control, the debugging facilities can be made to come into play at these statements to cause the dumping of the contents of any desired storage locations.

The expressions in Reference A2 for the mean orbital elements of the sun and of the moon are given in powers of T, Julian centuries of 36525 days counted from the epoch 1900 Jan 0.5. When some of these expressions are evaluated for T near 0.6, the results approach 400 radians; it, therefore, seemed desirable to bring the zero of time for evaluating these expressions closer to the present. There are 22279.5 days between 1900 Jan 0.5 and 1961 Jan 0.0, and if  $T'$  represents the number of days from 1961 Jan 0.0 to the time of interest, T can be written as  $T = (22279.5 + T')/36525$ . When this substitution is made and the expressions for the orbital elements are obtained in powers of  $T'$ , the terms containing  $T'^2$ ,  $T'^3$ , . . . are of no significance with single precision arithmetic. Next, to avoid restricting the zero of time associated with the input and output to 1961 Jan 0.0,  $T'$  can be written as  $T' = t_{REF} + t$ , where  $t_{REF}$  is the number of days (including any fraction) from 1961 Jan 0.0 to the desired zero of time associated with the input and output. One point is to be stressed. In the O-type output the independent variable, time, is with respect to the  $t_{REF}$  which was part of the input data from which the output resulted. When this O-type output is later used as a set of initial values of the variables, the correct value of  $t_{REF}$  to be used with it is the one that was associated with the O-type output, since the normal initial time input quantity is overridden by the time associated with the five dependent variables in the O-type output (and input).

## Use of Program and Input Data Cards

At this installation logical tape unit 1 is the IBM 709/7090 FORTRAN Monitor system tape. The input data are read from logical tape unit 2, and the values of the six variables (i.e., the time and the five orbital elements) at the end of each integration step, as well as any messages, are written on logical tape unit 3. Additional optional output (i.e., the values of the long range derivatives of the elements) is available on a logical tape unit specified by the input quantity ITP. Note that as a precaution statement 26 in the main program requires ITP to be larger than 3; if logical tape references are altered in the input and output statements, this statement should be reviewed for compatibility. The additional optional output is suppressed by using  $ITP = 0$ . No end-of-files are written on the output tapes, which are meant to be printed under program control. The output does not exceed 120 columns. The program is self-initializing, so that each time that the program is used any number of sets of input data can follow each other. For an example, the running time on the IBM 7090 is about 1 second per integration step when  $NDU = 24$ . As explained in the introduction, for the set of six

variables there are two input data formats available. If the input quantity IOCT on card 2 equals -1, the input quantity T on card 2 is used, and the input values of the five dependent variables occupy five E-type fields on card 3. If IOCT = +1, the O-type output from the end of a previous run is being used as a set of initial values of the six variables and occupies six O-type fields on card 3; the input quantity T on card 2 is ignored; and the input quantity TREF on card 2 must equal the TREF that was part of the input data from which resulted the O-type output which is being used as input.

The formats and contents of the three data cards follow. The version of card 3 for IOCT = +1 follows the version for IOCT = -1.

#### CARD 1. FORMAT (72Hb---b)

This card is used as the first line of any output for identification purposes and may contain any information in Hollerith. Since the output tapes are meant to be printed under program control, the first column on this card should be the print control character.

#### CARD 2. FORMAT (E14.8,2F10.3,I5,2F10.3,I3,5I2)

1. TREF = number of days (including any fraction) from 1961 Jan 0.0 to the zero of time associated with the input and output.
2. T = number of days (including any fraction) from the zero of time determined by TREF to the epoch of the orbital elements on card 3, if IOCT = -1. If IOCT = +1, this item is ignored and may be left blank. (IOCT is item 11 on this card.)
3. DT = integration step in days (negative sign is to be used when integrating backwards in time).
4. NDT = number of integration steps to be used unless difficulty is encountered.
5. PERMIN = minimum allowable value of  $a(1 - e)$  in kilometers.
6. CRIT = maximum allowable increment in degrees in any integration step in the argument of perigee or in the right ascension of the ascending node.
7. NDU = number of intervals for averaging over the orbit of the satellite in calculating the gravitational effect of the moon. (Suggest about 24, maximum is 360.)
8. ISUN = 1 to include the gravitational effect of the sun, = 0 to ignore it.
9. IMOON = 1 to include the gravitational effect of the moon, = 0 to ignore it.
10. IH2 = 1 to include the gravitational effect of the second earth harmonic, = 0 to ignore it.
11. IOCT = -1 if the initial values of the orbital elements and the time to epoch are expressed as decimal numbers, = +1 if the O-type output from the end of a previous run is being used as input. See further explanation above.
12. ITP = the logical number of the tape unit to be used if the additional optional output is desired, = 0 if this output is to be suppressed. (Note that statement 26 in the main program requires ITP to be larger than 3.)

CARD 3 (Used with IOCT = -1). FORMAT (5E14.8)

1.  $\omega$  = argument of perigee of the satellite orbit measured from the ascending node in degrees at the epoch on card 2.
2.  $\theta$  = right ascension of the ascending node of the satellite orbit on the earth equator in degrees at the epoch on card 2.
3.  $i$  = inclination of the satellite orbit with respect to the earth equator in degrees at the epoch on card 2;  $\sin i$  must not be  $0^\circ$  to avoid zero divisor. Program expects the inclination to be in the range  $0 < i < 180^\circ$ .
4.  $e$  = eccentricity of the satellite orbit at the epoch on card 2; must not be 0 or 1 to avoid zero divisor. Program expects the eccentricity to be in the range  $0 < e < 1$ .
5.  $a$  = semi-major axis of the satellite orbit in kilometers at the epoch on card 2.

CARD 3 (Used with IOCT = +1). FORMAT (6O12)

This card contains the O-type output (72 octal digits taken in order) from the end of a previous run, which is being extended.

### Expressions for Derivatives of Elements due to Gravitational Effect of the Sun

Equations (48), (49), (50) and (62) of Reference A1, which were obtained from the second Legendre polynomial, are\*

$$\sin i \frac{d\theta}{dt} = \frac{3m' n}{2\sqrt{1-e^2}} \left(\frac{a}{a'}\right)^3 \left(\frac{a'}{r'}\right)^3 \left[ (1+4e^2) (\hat{u} \cdot \hat{P}) \sin \omega + (1-e^2) (\hat{u} \cdot \hat{Q}) \cos \omega \right] (\hat{u} \cdot \hat{R}) ,$$

$$\frac{di}{dt} = \frac{3m' n}{2\sqrt{1-e^2}} \left(\frac{a}{a'}\right)^3 \left(\frac{a'}{r'}\right)^3 \left[ (1+4e^2) (\hat{u} \cdot \hat{P}) \cos \omega - (1-e^2) (\hat{u} \cdot \hat{Q}) \sin \omega \right] (\hat{u} \cdot \hat{R}) ,$$

$$\frac{de}{dt} = \frac{3m' n \sqrt{1-e^2}}{2} \left(\frac{a}{a'}\right)^3 \left(\frac{a'}{r'}\right)^3 [-5e (\hat{u} \cdot \hat{P})(\hat{u} \cdot \hat{Q})] ,$$

and

$$\frac{d\omega}{dt} = \frac{3m' n \sqrt{1-e^2}}{2} \left(\frac{a}{a'}\right)^3 \left(\frac{a'}{r'}\right)^3 [4(\hat{u} \cdot \hat{P})^2 - (\hat{u} \cdot \hat{Q})^2 - 1] - \cos i \frac{d\theta}{dt} ,$$

where, with sufficient accuracy,

$$\left(\frac{a'}{r'}\right)^3 = (1-e'^2)^{-3/2} + 3e' \cos g' .$$

---

\*The symbol  $\hat{\cdot}$  denotes a unit vector.

The expression in the reference for  $\hat{u}$ , the unit vector toward the sun, is replaced in the program by

$$\hat{u} = \hat{i} \cos \lambda' + \hat{j} \cos \epsilon \sin \lambda' + \hat{k} \sin \epsilon \sin \lambda' ,$$

where

$$\lambda' = L' + 2e' \sin g' .$$

## Constants in Arithmetic Statements

The explanations of the various numerical quantities appearing in the main program are given in the following list in their order of appearance. The numerical coefficients for computing ASER and BSER in the subroutine are taken directly from the development of the method. It must be remembered that the refinement of physical quantities is a continuing process. The terminal zero of many of the numerical quantities in the program is of no significance.

1.  $YV = \sin \epsilon$ ,  $YVR = \cos \epsilon$ , where  $\epsilon$  = mean obliquity of the ecliptic. For 1961 Jan 0.0,  $\epsilon = 23^\circ 26' 39.''68$  and  $d\epsilon/dt = -3.6 \times 10^{-7}/\text{day}$ , which is negligible here (Reference A2, p. 98).
2.  $\text{COA} = \pi/180^\circ$ ,  $\text{COB} = 180^\circ/\pi$ ,  $\text{RSEC} = \text{seconds of arc/radian}$ .
3.  $\text{RE} = \text{radius of earth in kilometers}$  (Reference A3, p. 2).

$$4. A4S = \frac{m'_s \sqrt{GM_E}}{a'^3} = \frac{m'_s \sqrt{GM_E} n'^2}{a'^3 n'^2} = \frac{m'_s \sqrt{GM_E} n'^2}{G(M_s + M_E + M_M)}$$

$$= \frac{m'_s \sqrt{GM_E} n'^2}{GM_E \left( \frac{M_s}{M_E} \right) \left( 1 + \frac{M_E + M_M}{M_s} \right)} = \frac{n'^2}{\sqrt{GM_E} \left( 1 + \frac{M_E + M_M}{M_s} \right)}$$

$$= \frac{(1.7201970 \times 10^{-2} \text{ rad/day})^2}{\left( \sqrt{398603.2} \text{ km}^{3/2}/\text{sec} \right) \left( 1 + \frac{1 + 1/81.335}{332951.3} \right)}$$

$$= 2.763214 \times 10^{-6} / (R_E^{3/2} \text{ day}) ,$$

where  $m'_s = M_s/M_E$  (References A2, p. 98 and A3, p. 2, 5, and 11).

5.  $\text{APW} = \text{mean lunar distance in earth radii} = (384400 \text{ km}, \text{Reference A4})$ .
6.  $\text{EPW} = \text{eccentricity of lunar orbit, ESQOP} = 1 - (\text{EPW})^2$  (Reference A2, p. 107).
7.  $\text{SSIM} = 2\gamma\sqrt{1-\gamma^2}$ ,  $\text{CSIM} = 1 - 2\gamma^2$ , where  $\gamma = \text{sine of half the inclination of the lunar orbit to the ecliptic}$  (Reference A2, p. 107).
8.  $\text{WKM} = -2\sqrt{GM_E} m'_M/a'^2 = -2 \left( \sqrt{398603.2} \text{ km}^{3/2}/\text{sec} \right) (1/81.335)/(384400 \text{ km})^2 = -7.2497 \times 10^{-4} / (R_E^{1/2} \text{ day})$ , where  $m'_M = M_M/M_E$  (References A3, p. 2 and 5 and A4).

9.  $H_2 = J\sqrt{GM_E} = (1.62345 \times 10^{-3}) (\sqrt{398603.2} \text{ km}^{3/2}/\text{sec}) = 1.73852 \times 10^{-1} \text{ re}^{3/2}/\text{day}$ , where  
 $J_n = J\sqrt{GM_E/a^{3/2}}$  (Reference A3, p. 2).
10.  $GEPRS = g' =$  mean anomaly of the sun as a linear function of time in days from 1961 Jan 0.0 (Reference A2, p. 98).
11.  $TRUL = \lambda' = L' + 2e' \sin g'$ .  $L'$  = mean longitude of the sun as a linear function of time in days from 1961 Jan 0.0.  $e'$  = eccentricity of the solar orbit for 1961 Jan 0.0;  $de'/dt = -1.1 \times 10^{-9}/\text{day}$ , which is negligible here (Reference A2, p. 98).
12.  $TGLS = (a'/r')^3$  for the sun =  $(1 - e'^2)^{-3/2} + 3e' \cos g'$ , with sufficient accuracy (Reference A1).
13.  $SOMPW = \Gamma' - \theta' =$  argument of the mean lunar perigee measured from the ascending node as a linear function of time in days from 1961 Jan 0.0 (Reference A2, p. 107).
14.  $COMPW = \varrho' =$  longitude of the mean ascending node of the lunar orbit on the ecliptic as a linear function of time in days from 1961 Jan 0.0 (Reference A2, p. 107).

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      XZ,RMX,RMY,RMZ,UDN,WKM,KKA,N,NDU,AW,SQA,APW,EW,SQE,EPW,ESQOP,SSI,CS
      XI,SSO,CSO,RKAL,RKELP,RKIL,RKCOL,RKPIL,RKLL
C PROLOGUE
      IF ACCUMULATOR OVERFLOW 2,2
2  IF DIVIDE CHECK 4,4
4  YV=3.97858270E-1
      YVR=9.17446890E-1
      COA=1.74532925E-2
      COB=57.2957795
      RSEC=206264.806
      RE=6378.1650
      A4S=2.7632140E-6
      APW=60.26810
      EPW=5.49004890E-2
      ESQCP=9.96985936E-1
      SSIM=8.96834480E-2
      CSIM=9.95970320E-1
      WKM=-7.24970E-4
      H2=1.738520E-1
C INPUT AND HEADINGS
6  N=0
      READ INPUT TAPE 2,8
8  FORMAT (72H
      X
      )
      WRITE OUTPUT TAPE 3,8
      READ INPUT TAPE 2,10,TREF,T,DT,NDT,PERMIN,CRIT,NDU,ISUN,IMON,IH2,
      XIOCT,ITP
10 FORMAT (E14.8,2F10.3,I5,2F10.3,I3,5I2)
      IF (IOCT) 12,138,16
12 READ INPUT TAPE 2,14,SOP,COP,FI,EO,AK
14 FORMAT (5E14.8)
      AC=AK/RE
      FIRO=FI*COA
      SORO=SOP*COA
      CORO=COP*COA
      GO TO 20
16 READ INPUT TAPE 2,18,T,SORO,CORO,FIRO,EO,AO
18 FORMAT (60I2)
      AK=AO*RE
      FI=FIRO*COB
      SOP=SORO*COB
      COP=CORO*COB
20 WRITE OUTPUT TAPE 3,22,T,DT,NDT,TREF,SOP,COP,FI,EO,AK,NDU,ISUN,IMO
      XON,IH2,XIOCT,ITP,PERMIN,CRIT
22 FORMAT (18H0 T START (DAYS) =F10.3,14H , DELTA T =F10.3,20H ,
      XNO CF DELTA T =I6.18H , T REFERENCE =E16.8/24H ARG OF PERIGEE (
      XDEG) =E16.8,21H , RA OF ASC NODE =E16.8,18H , INCLINATION =E16
      X.8/16H ECCENTRICITY =E16.8,26H , SEMIMAJOR AXIS (KM) =E16.8,2H
      X,I5,31H INTERVALS OVER SATELLITE ORBIT/31H GRAVITATIONAL EFFECT O
      XF SUN *I2,14H , OF MOON *I2,31H , OF 2ND HARMONIC OF EARTH *I2

```

```

X,11H , IOCT =I3,10H , ITP =I3/96H TIME = 0 CORRESPONDS TO JAN
X 0.0, 1961 + T REFERENCE DAYS , MINIMUM VALUE OF A*(1.0-E) (KM)
X=E16.8/90H MAXIMUM INCREMENT (DEG) IN ANY INTEGRATION STEP IN ARG
X OF PERIGEE OR IN RA OF ASC NODE =E15.8)
      WRITE OUTPUT TAPE 3,24
24 FORMAT (114HO TIME (DAYS)          ARG PERIGEE (DEG)  RA ASC NODE (D
XEG)  INCLINATION (DEG)  ECCENTRICITY  SEMIMJR AXIS (KM))
      IF (ITP) 138,32,26
26 IF (ITP-3) 138,138,28
28 WRITE OUTPUT TAPE ITP,8
      WRITE OUTPUT TAPE ITP,22,T,DT,NDT,TREF,SOP,COP,FI,E0,AK,NDU,ISUN,I
XMOCN,IH2,ICCT,ITP,PERMIN,CRIT
      WRITE OUTPUT TAPE ITP,30
30 FORMAT (117HO DERIVATIVES OF ELEMENTS IN SEC OF ARC/DAY EXCEPT A I
XN KM/DAY AND E IN 1/DAY. S FOR SOLAR, L LUNAR, AND H 2ND HARM./11
X8HO TIME (DAYS)      MEAN LONGITUDE,L ARG PERIGEE,L   RA ASC NODE
X,L  INCLINATION,L  ECCENTRICITY,L  SEMIMJR AXIS,L/101H ARG P
XERIGEE,H  RA ASC NODE,H  ARG PERIGEE,S  RA ASC NODE,S  INC
XLINATION,S  ECCENTRICITY,S)
C INITIALIZATION
32 TF=T+TREF
      DT2=0.50*DT
      L=1
      KKA=0
      A1=0.0
      E1=0.0
      FIR1=0.0
      SOR1=0.0
      COR1=0.0
      SOP1=0.0
      COP1=0.0
      RKAL=0.0
      RKELP=0.0
      RKIL=0.0
      RKSCL=0.0
      RKCCL=0.0
      RKLL=0.0
      RKESP=0.0
      RKIS=0.0
      RKSCS=0.0
      RKCCS=0.0
      RKSCH=0.0
      RKCCH=0.0
      A=A0
      E=E0
      FIR=FIR0
      SCR=SCR0
      COR=COR0
      SOD=SOP
      COD=CCP
      IF (NDU) 138,38,34
34 ENDU=NDU
      UDN=1.0/ENDU
      DUR=6.28318531*UDN
      DC 36 JZ=1,NDU
      BJZ=JZ-1
      UZ=BJZ*DUR
      SING(JZ)=SINF(UZ)
36 CCSG(JZ)=CCSF(UZ)
C RUNGE-KUTTA
38 TW=TF

```

```

AW=A0
EW=E0
FIRW=FIRO
SORW=SORO
CORW=CORO
N=1
ASSIGN 42 TC NRET
GO TO 90
40 AW=A
EW=E
FIRW=FIR
SORW=SOR
CORW=COR
N=1
ASSIGN 42 TC NRET
GO TO 98
42 AKP=A*RE
PER=AKP*(1.0-E)
FID=FIR*CCB
IF ACCUMULATOR OVERFLOW 144,44
44 IF DIVIDE CHECK 148,46
C REARRANGEMENT OF CPUTPUT IS MADE BY CHANGING STATEMENTS 24, 46, 48
46 WRITE CPUTPUT TAPE 3,48,T,SOD,COD,FID,E,AKP
48 FORMAT (1H0E15.8,5E19.8)
IF (ITP) 138,54,50
50 RKALP=RKAL*RRE
RKILP=RKIL*RSEC
RKSOLP=RKSOL*RSEC
RKCOLP=RKCOL*RSEC
RKLLP=RKLL*RSEC
RKISP=RKIS*RSEC
RKSOSP=RKSOS*RSEC
RKCCSP=RKCOS*RSEC
RKSCHP=RKSOH*RSEC
RKCCHP=RKCOH*RSEC
WRITE OUTPUT TAPE ITP,52,T,RKLLP,RKSOLP,RKCOLP,RKILP,RKELP,RKALP,R
XKSOPH,RKCOHP,RKSOSP,RKCOSP,RKISP,RKESP
52 FORMAT (1H01PE14.7,6E17.7/E15.7,5E17.7)
54 IF (PER-PERMIN) 56,60,60
56 WRITE OUTPUT TAPE 3,58,PER,PERMIN
58 FORMAT (15HO A*(1.0-E) ISE16.8,16H KM , PERMIN =E15.8)
GO TO 142
60 IF (NDT) 138,142,62
62 RKAT=RKA
RKET=RKE
RKIT=RKI
RKSCT=RKS0
RKCCCT=RKCO
TW=TF+DT2
AW=A+0.50*RKA
EW=E+0.50*RKE
FIRW=FIR+0.50*RKI
SORW=SOR+0.50*RKS0
CORW=CCR+0.50*RKCO
N=2
ASSIGN 64 TC NRET
GO TO 90
64 RKAT=RKAT+2.0*RKA
RKET=RKET+2.0*RKE
RKIT=RKIT+2.0*RKI
RKSCT=RKSCT+2.0*RKS0

```

```

RKCOT=RKCOT+2.0*RKCO
AW=A+0.50*RKA
EW=E+0.50*RKE
FIRW=FIR+0.50*RKI
SORW=SOR+0.50*RKSO
CORW=CR+0.50*RKCO
N=3
ASSIGN 66 TC NRET
GO TO 98
66 RKAT=RKAT+2.0*RKA
RKET=RKET+2.0*RKE
RKIT=RKIT+2.0*RKI
RKSOT=RKSOT+2.0*RKSO
RKCOT=RKCOT+2.0*RKCO
TW=TF+DT
AW=A+RKA
EW=E+RKE
FIRW=FIR+RKI
SORW=SOR+RKS0
CORW=CCR+RKC0
N=4
ASSIGN 68 TO NRET
GO TO 90
68 RKSCT=(RKSCT+RKS0)/6.0
RKSOTB=RKSOT*COB
RKCCT=(RKCOT+RKC0)/6.0
RKCCTB=RKCOT*CCB
IF (ABSF(RKSOTB)-CRIT) 78,78,70
70 WRITE OUTPUT TAPE 3,72,RKSOTB,CRIT
72 FORMAT (39HO INCREMENT IN ARG OF PERIGEE WOULD BEE16.8,15H DEG ,
X CRIT =E15.8)
IF (ABSF(RKCOTB)-CRIT) 142,142,74
74 WRITE OUTPUT TAPE 3,76,RKCOTB,CRIT
76 FORMAT (39HO INCREMENT IN RA OF ASC NODE WOULD BEE16.8,15H DEG ,
X CRIT =E15.8)
GO TO 142
78 IF (ABSF(RKCOTB)-CRIT) 80,80,74
80 A1=A1+(RKAT+RKA)/6.0
A=AC+A1
E1=E1+(RKET+RKE)/6.0
E=E0+E1
FIR1=FIR1+(RKIT+RKI)/6.0
FIR=FIR0+FIR1
SOR1=SOR1+RKSOT
SOP1=SOP1+RKSOTB
SOD=SOP+SOP1
IF (ABSF(SCR1)-3.14159265) 84,84,82
82 SOR1=SOR1-SIGNF(6.28318531,SOR1)
SZ=SIGNF(360.0,SOP1)
SOP1=SOP1-SZ
SCP=SCP+SZ
84 SOR=SOR0+SOR1
COR1=COR1+RKCOT
COP1=CCP1+RKCCTB
CCD=CCP+CCP1
IF (ABSF(COR1)-3.14159265) 88,88,86
86 COR1=COR1-SIGNF(6.28318531,COR1)
SZ=SIGNF(360.0,COP1)
COP1=CCP1-SZ
COP=COP+SZ
88 COR=CCRO+COR1

```

```

L=2
120 GO TO (122,142),L
122 SQA=SQRTF(AW)
SQA3=SQA*AW
SQE=SQRTF(ESR)
SSI=SINF(FIRW)
CSI=CCSF(FIRW)
SSO=SINF(SORW)
CSC=CCSF(SORW)
SCC=SINF(CORW)
CCC=CCSF(CORW)
SSSC=SSC*SCO
SSCC=SSC*CCO
CSSC=CSC*SCO
CSOC=CSC*CCO
PX=CSSC-SSSC*CSI
PY=CSSC+SSCC*CSI
PZ=SSC*SSI
QX=-SSCC-CSSC*CSI
QY=-SSSC+CSSC*CSI
QZ=CSC*SSI
RX=SSC*SSI
RY=-CCO*SSI
RZ=CSI
IF (ISUN) 138,126,124
C SCLAR GRAVITATIONAL PERTURBATION
124 ONFCR=1.0+4.0*EW2
FBA=1.50*A4S*SQA3*TGLS
UDCTP=UX*PX+UY*PY+UZ*PZ
UDCTQ=UX*QX+UY*QY+UZ*QZ
UDCTR=UX*RX+UY*RY+UZ*RZ
XBA=ONFCR*UDOTP
XBB=ESR*UDOTQ
XBC=FBA*UDOTR/SQE
XBD=FBA*SQE
RKIS=XBC*(XBA*CSC-XBB*SSO)
RKCCS=XBC*(XBA*SSC+XBB*CSC)/SSI
RKESP=XBD*(-5.0*EW*UDCTP*UDOTQ)
RKSCS=XHD*(4.0*UDCTP**2-UDOTQ**2-1.0)-CSI*RKCOS
126 IF (IMCCN) 138,132,128
C LUNAR GRAVITATIONAL PERTURBATION
128 CALL HALPH
IF (KKA) 152,130,152
130 RKSOL=RKPIL-RKCOL
132 IF (IH2) 138,136,134
C EARTH OBLATENESS PERTURBATION
134 HAR=H2/(SQA3*(AW*ESR)**2)
RKSOH=HAR*(2.0-2.50*SSI*SSI)
RKCCH=-HAR*CSI
136 RKA=RKAL*DT
RKE=(RKELP+RKESP)*DT
RKI=(RKIL+RKIS)*DT
RKSG=(RKSCL+RKSOL+RKSOH)*DT
RKCO=(RKCCL+RKCOS+RKCCH)*DT
GO TO NRET,(42,64,66,68)
C ERROR MESSAGES
138 L=2
      WRITE OUTPUT TAPE 3,140,NDT,NDU,ISUN,IMOON,IH2,IOCT,ITP,N
140 FORMAT (28H0 INCRRECT INTEGER NDT =I5,7H NDU =I5,8H ISUN =15
X,9H IMOON =I5,7H IH2 =I5,8H IOCT =I5,7H ITP =I5,8H , N =I2)
142 IF ACCUMULATOR OVERFLOW 144,154

```

```

      L=2
120  GO TO (122,142),L
122  SQA=SQRTF(AW)
      SQA3=SQA*AW
      SQE=SQRTF(ESR)
      SSI=SINF(FIRW)
      CSI=COSF(FIRW)
      SSO=SINF(SORW)
      CSC=COSF(SORW)
      SCC=SINF(CORW)
      CCC=COSF(CORW)
      SSSC=SSO*SCO
      SSCC=SSC*CCO
      CSSC=CSC*SCO
      CSOC=CSC*CCO
      PX=CSSC-SSSC*CSI
      PY=CSSC+SSCC*CSI
      PZ=SSO*SSI
      QX=-SSSC-CSSC*CSI
      QY=-SSSC+CSSC*CSI
      QZ=CSC*SSI
      RX=SCO*SSI
      RY=-CCO*SSI
      RZ=CSI
      IF (ISUN) 138,126,124
C     SOLAR GRAVITATIONAL PERTURBATION
124  ONFOR=1.0+4.0*EW2
      FBA=1.50*A4S*SQA3*TGLS
      UDOTP=UX*PX+UY*PY+UZ*PZ
      UDOTQ=UX*QX+UY*QY+UZ*QZ
      UDCTR=UX*RX+UY*RY+UZ*RZ
      XBA=ONFCR*UDOTP
      XBB=ESR*UDOTQ
      XBC=FBA*UDOTR/SQE
      XBD=FBA*SQE
      RKIS=XBC*(XBA*CSC-XBB*SSO)
      RKCCS=XBC*(XBA*SSC+XBB*CSO)/SSI
      RKESP=XBD*(-5.0*EW*UDOTP*UDOTQ)
      RKSCS=XBD*(4.0*UCCTP**2-UDOTQ**2-1.0)-CSI*RKCOS
126  IF (IMOCN) 138,132,128
C     LUNAR GRAVITATIONAL PERTURBATION
128  CALL HALPH
      IF (KKA) 152,130,152
130  RKSOL=RKPIL-RKCOL
132  IF (IH2) 138,136,134
C     EARTH OBLATENESS PERTURBATION
134  HAR=H2/(SQA3*(AW*ESR)**2)
      RKSOH=HAR*(2.0-2.50*SSI*SSI)
      RKCOH=-HAR*CSI
136  RKA=RKAL*DT
      RKE=(RKELP+RKESP)*DT
      RKI=(RKIL+RKIS)*DT
      RKSO=(RKSCL+RKSOS+RKSOH)*DT
      RKCO=(RKCOL+RKCOS+RKCOH)*DT
      GO TO NRET,(42,64,66,68)
C     ERROR MESSAGES
138  L=2
      WRITE OUTPUT TAPE 3,140,NDT,NDU,ISUN,IMOON,IH2,IOCT,ITP,N
140  FORMAT (28H0 INCORRECT INTEGER NDT =I5,7H NDU =I5,8H ISUN =I5
      X,9H IMOON =I5,7H IH2 =I5,8H IOCT =I5,7H ITP =I5,8H , N =I2)
142  IF ACCUMULATOR OVERFLOW 144,154

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144 WRITE OUTPUT TAPE 3,146,N
146 FORMAT (24HO MAIN ACC DVR , N =I2)
    IF DIVIDE CHECK 148,152
148 WRITE OUTPUT TAPE 3,150,N
150 FORMAT (24HO MAIN DIV CHK , N =I2)
C STATEMENT NUMBER FOR USING WITH DEBUG FACILITY IS 152
152 GO TO 6
154 IF DIVIDE CHECK 148,156
156 GO TO (158,152),L
C OUTPUT FOR RESTARTING WITH IOCT = +1
158 WRITE OUTPUT TAPE 3,160,T,SOR,COR,FIR,E,A
160 FORMAT (36HO OCTAL EQUIVALENT OF LAST LINE IS 6012)
    GO TO 6
    END

C SUBROUTINE FOR LUNAR GRAVITATIONAL EFFECTS USING HALPHEN'S METHOD.
C NASA-GSFC THEORETICAL DIV MATH-COMPUTING BR CODE 642 A J SMITH JR.
C DISCLAIMER-ALTHOUGH THIS PROGRAM HAS BEEN TESTED, NO WARRANTY,
C EXPRESSED OR IMPLIED, IS MADE BY NASA AS TO THE ACCURACY AND
C FUNCTIONING OF THE PROGRAM AND RELATED PROGRAM MATERIAL, NOR
C SHALL THE FACT OF DISTRIBUTION CONSTITUTE ANY SUCH WARRANTY,
C AND NO RESPONSIBILITY IS ASSUMED BY NASA.
C VARIABLES CONTAINING THE DIGIT ONE ONCE ARE A12, A31, AK1, AK12, AP1
C 2, AP31, CA12, CA31, F1, PP1, SUM1, Y1. TWICE ARE A11, AP11, CA11.
    SUBROUTINE HALPH
    DIMENSION SING(360),COSG(360)
    COMMON SING,CCSG,PX,PY,PZ,QX,QY,QZ,RX,RY,RZ,PMX,PMY,PMZ,QMX,QMY,QM
    XZ,RMX,RMY,RMZ,UDN,WKM,KKA,N,NDU,AW,SQA,APW,EW,SQE,EPW,ESQOP,SSI,CS
    XI,SSO,CSO,RKAL,RKELP,RKIL,RKCOL,RKPIL,RKLL
    IF ACCUMULATOR OVERFLOW 32,2
2 IF DIVIDE CHECK 36,4
4 AWP=AW/APW
    AWPSQE=AWP*SQE
    PPP=PMX*PX+PMY*PY+PMZ*PZ
    QPP=QMX*PX+QMY*PY+QMZ*PZ
    RPP=RMX*PX+RMY*PY+RMZ*PZ
    PPP=PMX*QX+PMY*QY+PMZ*QZ
    QPP=QMX*QX+QMY*QY+QMZ*QZ
    RPP=RMX*QX+RMY*QY+RMZ*QZ
    PPR=PMX*RX+PMY*RY+PMZ*RZ
    QPR=QMX*RX+QMY*RY+QMZ*RZ
    RPR=RMX*RX+RMY*RY+RMZ*RZ
    SUM1=0.0
    SUM2=0.0
    SUM3=0.0
    SUM4=0.0
    SUM5=0.0
    SUM6=0.0
    SUM7=0.0
    SUM8=0.0
    SUM9=0.0
    SUMA=0.0
    DO 14 J=1,NDU
    SU=SING(J)
    CU=COSG(J)
    CUE=CU-EW
    F1=AWP*CUE
    F2=AWPSQE*SU
    X=PPP*F1+PPC*F2
    BET=QPP*F1+QPC*F2

```

```

GAM=RPP*F1+RPQ*F2
ALF=X+EPW
ALF2=ALF**2
BET2=BET**2
GAM2=GAM**2
AK1=ALF2+BET2+GAM2-(1.0+ESQOP)
AK2=ESQOP*(1.0-ALF2-GAM2)-BET2-GAM2
AK12=AK1*AK2
AK3=ESQCP*GAM2
G2=(AK1**2-3.0*AK2)*1.3333333
G23=G2**3
G24=G2**0.250
G3=(2.0*AK1**3-9.0*AK12+27.0*AK3)*1.48148148E-1
CHI=27.0*G3**2/G23
IF (CHI) 28,6,10
6 WRITE CPUTUP TAPE 3,8,J,N
8 FORMAT (21H0 CHI IS 0.0 , J =I3,8H , N =I2)
10 SQCHI=SQRTF(CHI)
ZEE=(1.0-SQCHI)/(1.0+SQCHI)
FAC=(2.0/(1.0+SQCHI))**1.66666667E-1
FAC7=FAC**7
ASER={((((((+0.00018460*ZEE-0.00268490)*ZEE+0.01836830)*ZE
XE-0.07898380)*ZEE+0.24083300)*ZEE-0.55933290)*ZEE+1.04482500)*ZEE-
X1.65246820)*ZEE+2.33758320)*ZEE-3.13363650)*ZEE+4.19869700)*ZEE-5.
X86828430)*ZEE+8.89725570)*ZEE-15.5611925)*ZEE+36.9364569)*ZEE-379.
X917843)*2.72165527E-3*FAC7*G24/G23
BSER={(((((-0.00002050*ZEE+0.00029770)*ZEE-0.00204530)*ZE
XE+0.00883750)*ZEE-0.02710190)*ZEE+0.06337420)*ZEE-0.11936040)*ZEE+
X0.19070380)*ZEE-0.27325470)*ZEE+0.37249870)*ZEE-0.51060370)*ZEE+0.
X73743050)*ZEE-1.17690760)*ZEE+2.25631990)*ZEE-6.63081730)*ZEE+238.
X709421)*4.5C158158E-3*FAC/(G2*G24)
AK4=9.0*AK3-AK12
AK5=AK1*(AK12-3.0*AK3)-2.0*AK2**2
Y1=-1.50*G2
Y2=-Y1*AK3
Y3=-AK1/3.0
AP11=ALF2-1.0+Y3
AP22=BET2-ESQCP+Y3
AP33=GAM2+Y3
AP12=ALF*BET
AP23=BET*GAM
AP31=GAM*ALF
A11=AK4*(ALF2-1.0)+AK5+Y2
A22=AK4*(BET2-ESQOP)+AK5+Y2/ESQOP
A33=AK4*GAM2+AK5-Y1*(ALF2*ESQOP+BET2-ESQOP)
A12=AK4*AP12
A23=(AK4+Y1)*AP23
A31=(AK4+Y1*ESQOP)*AP31
CA11=ASER*A11+BSER*AP11
CA22=ASER*A22+BSER*AP22
CA33=ASER*A33+BSER*AP33
CA12=ASER*A12+BSER*AP12
CA23=ASER*A23+BSER*AP23
CA31=ASER*A31+BSER*AP31
PP1=WKM*(CA11*X+CA12*BET+CA31*GAM)
PP2=WKM*(CA12*X+CA22*BET+CA23*GAM)
PP3=WKM*(CA31*X+CA23*BET+CA33*GAM)
ECU=1.0-EW*CU
SMR=AWP*ECU
CPHI=X/SMR
CCHI=BET/SMR

```

```

CPSI=GAM/SMR
CPHIIPP=PPR
CCHIIPP=QPR
CPSIPP=RPR
CPHIP=CPSI*CCHIIPP-CCHI*CPSIPP
CCHIP=CPHI*CPSIPP-CPSI*CPHIP
CPSIP=CCHI*CPHIP-CPHI*CCHIP
SS=PP1*CPHI+PP2*CCHI+PP3*CPSI
TT=PP1*CPHIP+PP2*CCHIP+PP3*CPSIP
WW=PP1*CPHIP+PP2*CCHIP+PP3*CPSIPP
C2U=CU*CU-SU*SU
SUM1=SUM1+SS*SU
SUM2=SUM2+SS*CUE
SUM3=SUM3+SS*ECU*ECU
SUM4=SUM4+TT
SUM5=SUM5+TT*CU
SUM6=SUM6+TT*C2U
Y4=TT*SU
SUM7=SUM7+Y4
SUM8=SUM8+Y4*ECU
Y5=WW*ECU
SUM9=SUM9+Y5*SU
SUMA=SUMA+Y5*CUE
IF ACCUMULATOR OVERFLOW 18,12
12 IF DIVIDE CHECK 24,14
14 CCNTINUE
SQAUDN=SQA*UDN
SQAUED=SQAUDN/SQE
SQEM=SQE*SUM9
RKIL=SQAUED*(SUMA*CSO-SQEM*SSO)
SINCDE=SQAUED*(SUMA*SSO+SQEM*CSO)
RKCCL=SINODE/SSI
Y6=SINODE*SSI/(1.0+CSI)
SQAUN=SQAUDN*SQE
RKELP=SQAUN*(SQE*SUM1-EW*(1.50*SUM4+0.50*SUM6)+2.0*SUM5)
EPI=SQAUN*(-SUM2+SUM7*SQE+SUM8/SQE)
RKPL=SQAUN2*EPI/EW+Y6
SQAU2=2.0*SQAUDN
RKAL=SQAU2*AW*(EW*SUM1+SQE*SUM4)
RKLL=-SQAU2*SUM3+EPI*EW/(1.0+SQE)+Y6
IF ACCUMULATOR OVERFLOW 18,16
16 IF DIVIDE CHECK 24,42
C ERRCR MESSAGES
18 WRITE CPUTPUT TAPE 3,20,J,N
20 FORMAT (25HO HALPH ACC OVR , J =I3,8H , N =I2)
22 IF DIVIDE CHECK 24,40
24 WRITE CPUTPUT TAPE 3,26,J,N
26 FORMAT (25HO HALPH DIV CHK , J =I3,8H , N =I2)
GO TO 40
28 WRITE CPUTPUT TAPE 3,30,CHI,J,N
30 FORMAT (9HO CHI ISE16.8,8H , J =I3,8H , N =I2)
IF ACCUMULATOR OVERFLOW 18,22
32 WRITE CPUTPUT TAPE 3,34,N
34 FORMAT (36HO ACC OVR ON ENTERING HALPH , N =I2)
IF DIVIDE CHECK 36,40
36 WRITE CPUTPUT TAPE 3,38,N
38 FORMAT (36HC DIV CHK ON ENTERING HALPH , N =I2)
C STATEMENT NUMBER FOR USING WITH DEBUG FACILITY IS 40
40 KKA=90
42 RETURN
END

```

1 SAMPLE RUN WITH INITIAL VALUES FOR ELEMENTS FROM TABLE 3, SEE FIGS 1-9.

1.CEC	0.C	20.0	3 6378.1650	5.C 24 1 1 1-1 5
155.0610CEC	163.0392CEO	35.38820E0	0.954361CEC	145036.3E0

SAMPLE RUN WITH INITIAL VALUES FOR ELEMENTS FROM TABLE 3, SEE FIGS 1-9.

T START (DAYS) = C., DELTA T = 20.CCC, NO OF DELTA T = 3, T REFERENCE = 0.09999999E 01  
 ARG OF PERIGEE (DEG) = 0.15506100E 03, RA OF ASC NODE = C.16303920E 03, INCLINATION = 0.35388199E 02  
 ECCENTRICITY = 0.95436100E 00, SEMIMAJOR AXIS (KM) = 0.14503630E 06, 24 INTERVALS OVER SATELLITE ORBIT  
 GRAVITATIONAL EFFECT OF SUN \* 1, OF MOON \* 1, OF 2ND HARMONIC OF EARTH \* 1, ICCT = -1, ITP = 5  
 TIME = 0 CORRESPONDS TO JAN 0.0, 1961 + T REFERENCE DAYS, MINIMUM VALUE OF A\*(1.0-E) (KM) = 0.63781650E 04  
 MAXIMUM INCREMENT (DEG) IN ANY INTEGRATION STEP IN ARG OF PERIGEE OR IN RA OF ASC NODE = 0.49999999E 01

TIME (DAYS)	ARG PERIGEE (DEG)	RA ASC NODE (DEG)	INCLINATION (DEG)	ECCENTRICITY	SEMINJOR AXIS (KM)
0.	C.15506100E 03	0.16303920E 03	C.35388198E 02	0.95436100E 00	0.14503630E 06
0.20000000E 02	C.15899024E 03	0.15845156E 03	0.41536867E 02	C.94906449E 00	0.14503629E 06
0.40000000E 02	C.16141555E 03	0.15568403E 03	C.46368806E 02	C.93971051E 00	0.14503629E 06
0.59999999E 02	C.16275559E 03	0.15440386E 03	C.48842262E 02	C.92668819E 00	0.14503629E 06

CORRECT EQUIVALENT OF LAST LINE IS 20674000000202553462737202530742041200664352652200732355577205553652001

SAMPLE RUN WITH INITIAL VALUES FOR ELEMENTS FROM TABLE 3, SEE FIGS 1-9.

T START (DAYS) = C., DELTA T = 20.CCC, NO OF DELTA T = 3, T REFERENCE = 0.09999999E 01  
 ARG OF PERIGEE (DEG) = 0.15506100E 03, RA OF ASC NODE = 0.16303920E 03, INCLINATION = 0.35388199E 02  
 ECCENTRICITY = 0.95436100E 00, SEMIMAJOR AXIS (KM) = 0.14503630E 06, 24 INTERVALS OVER SATELLITE ORBIT  
 GRAVITATIONAL EFFECT OF SUN \* 1, OF MOON \* 1, OF 2ND HARMONIC OF EARTH \* 1, ICCT = -1, ITP = 5  
 TIME = 0 CORRESPONDS TO JAN 0.0, 1961 + T REFERENCE DAYS, MINIMUM VALUE OF A\*(1.0-E) (KM) = 0.63781650E 04  
 MAXIMUM INCREMENT (DEG) IN ANY INTEGRATION STEP IN ARG OF PERIGEE OR IN RA OF ASC NODE = 0.49999999E 01

DERIVATIVES OF ELEMENTS IN SEC OF ARC/DAY EXCEPT A IN KM/DAY AND E IN 1/DAY. S FOR SOLAR, L LUNAR, AND H 2ND HARM.

TIME (DAYS)	MEAN LONGITUDE,L ARG PERIGEE,H RA ASC NODE,H	ARG PERIGEE,L ARG PERIGEE,S RA ASC NODE,S	RA ASC NODE,L RA ASC NODE,S	INCLINATION,L INCLINATION,S	ECCENTRICITY,L ECCENTRICITY,S	SEMINJOR AXIS,L
0. 9.3375903E 01	-6.3592452E 01 -6.5535837E 01	3.2882873E 02 4.2412151E 02	-4.0253832E 02 -5.0986295E 02	4.8453318E 02 6.2352197E 02	-2.6416264E-04 8.1797698E-05	-2.0967473E-06
2.0000000E C1 5.8449001E C1	-5.6560799E 01 -4.8572049E 01	1.8746596E 02 3.1798989E 02	-2.4520409E 02 -3.6685045E 02	4.0261185E 02 6.3889800E 02	-3.0410490E-04 -5.7270955E-05	-2.5160967E-06
4.0000000E C1 3.2281266E C1	-5.1650242E 01 -3.2268007E 01	1.1800913E 02 1.7363761E 02	-1.5977575E 02 -1.5545185E 02	3.1934942E 02 3.4590623E 02	-3.4528292E-04 -2.2481838E-04	-2.5160967E-06
5.9999999E C1 1.8683526E C1	-5.1080142E 01 -2.1056731E 01	9.0366610E 01 6.2000962E 01	-1.1918123E 02 8.1727835E 00	2.6021686E 02 -2.1088990E 01	-3.8194373E-04 -3.3475969E-04	-3.7741451E-06

1CONTINUATION OF SAMPLE RUN TO ILLUSTRATE AN INCORRECT INTEGER (DT=-2).  
1.CEC 20.0 -2 6378.1650 5.C 24 1 1 1+1 0  
20674CCCCCCC2C25534627372C253074204120066435265220C732355577205553652001

CONTINUATION OF SAMPLE RUN TO ILLUSTRATE AN INCORRECT INTEGER (DT=-2).

T START (DAYS) = 60.000 , CELTA T = 20.000 , NO OF DELTA T = -2 , T REFERENCE = 0.09999999E 01  
ARG OF PERIGEE (DEG) = C.16275559E 03 , RA OF ASC NODE = C.15440385E 03 , INCLINATION = C.48842262E 02  
ECCENTRICITY = C.92668819E 00 , SEMIMAJOR AXIS (KM) = 0.14503629E 06 , 24 INTERVALS OVER SATELLITE ORBIT  
GRAVITATIONAL EFFECT OF SUN \* 1 , OF 2ND HARMONIC OF EARTH \* 1 , ICCT = 1 , ITP = 0  
TIME = C CORRESPONDS TO JAN 0.0, 1961 + T REFERENCE DAYS , MINIMUM VALUE OF A\*(1.0-E) (KM) = 0.63781650E 04  
MAXIMUM INCREMENT (DEC) IN ANY INTEGRATION STEP IN ARG OF PERIGEE OR IN RA OF ASC NODE = 0.49999999E 01

TIME (DAYS)	ARG PERIGEE (DEG)	RA ASC NODE (DEG)	INCLINATION (DEG)	ECCENTRICITY	SEMINJR AXIS (KM)
0.59999999E 02	C.16275559E 03	0.15440385E 03	C.48842262E 02	C.92668819E 00	0.14503629E 06

INCORRECT INTEGER NET = -2 NDU = 24 ISUN = 1 IMODN = 1 IH2 = 1 ICCT = 1 ITP = 0 , N = 1

1CONTINUATION OF SAMPLE RUN TO ILLUSTRATE AN INCREMENT BEING TOO LARGE.  
1.CEC 20.0 200 6378.1650 C.1C 24 1 1 1+1 0  
20674CCCCCCC2C25534627372C253074204120066435265220C732355577205553652001

CONTINUATION OF SAMPLE RUN TO ILLUSTRATE AN INCREMENT BEING TOO LARGE.

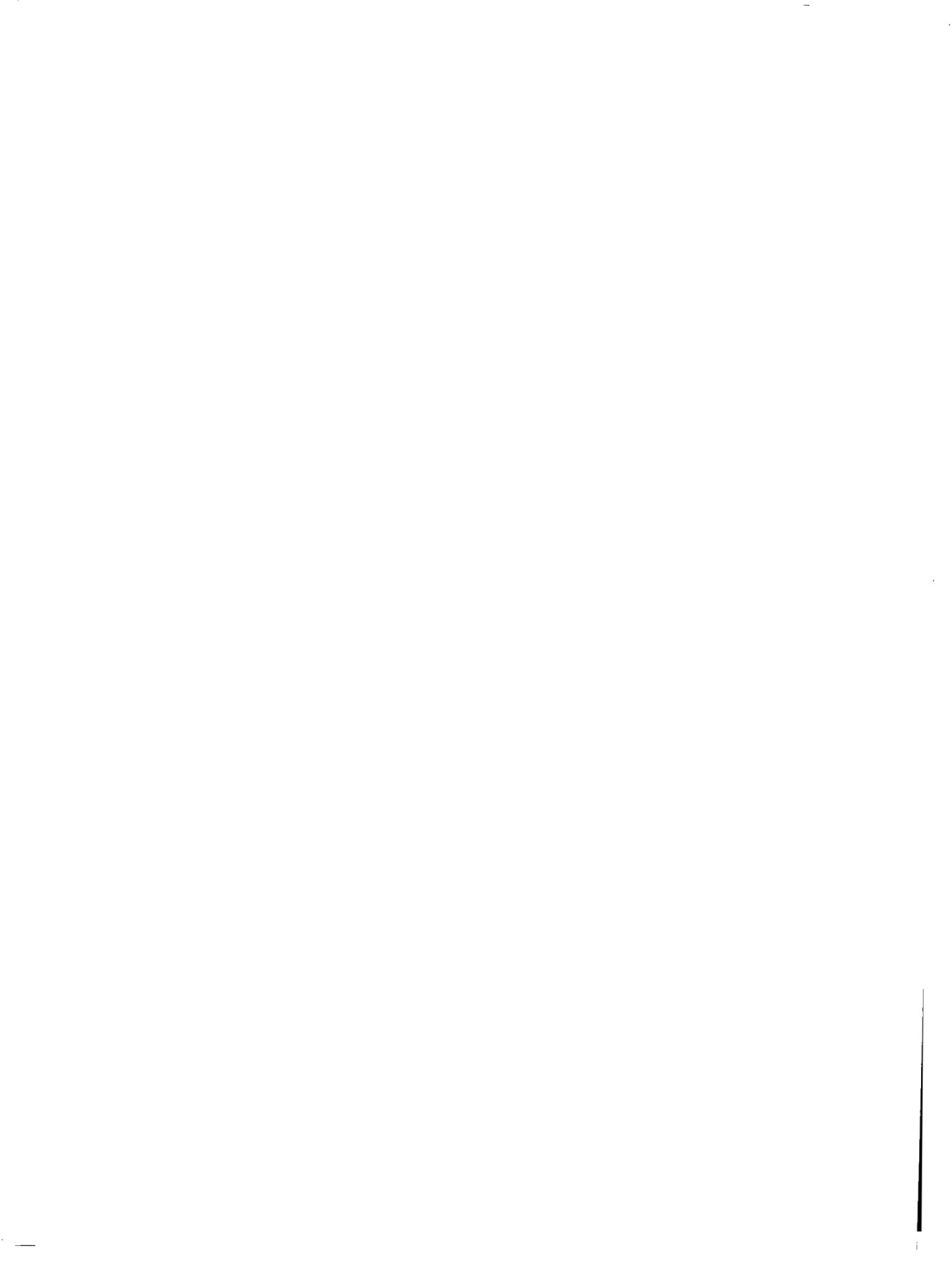
T START (DAYS) = 60.000 , CELTA T = 20.000 , NO OF DELTA T = 200 , T REFERENCE = 0.09999999E 01  
ARG OF PERIGEE (DEG) = C.16275559E 03 , RA OF ASC NODE = C.15440385E 03 , INCLINATION = C.48842262E 02  
ECCENTRICITY = C.92668819E 00 , SEMIMAJR AXIS (KM) = 0.14503629E 06 , 24 INTERVALS OVER SATELLITE ORBIT  
GRAVITATIONAL EFFECT OF SUN \* 1 , OF 2ND HARMONIC OF EARTH \* 1 , ICCT = 1 , ITP = 0  
TIME = C CORRESPONDS TO JAN 0.0, 1961 + T REFERENCE DAYS , MINIMUM VALUE OF A\*(1.0-E) (KM) = 0.63781650E 04  
MAXIMUM INCREMENT (DEC) IN ANY INTEGRATION STEP IN ARG OF PERIGEE OR IN RA OF ASC NODE = 0.09999999E-00

TIME (DAYS)	ARG PERIGEE (DEG)	RA ASC NODE (DEG)	INCLINATION (DEG)	ECCENTRICITY	SEMINJR AXIS (KM)
0.59999999E 02	0.16275559E 03	0.15440385E 03	C.48842262E 02	0.92668819E 00	0.14503629E 06

INCREMENT IN ARG OF PERIGEE WOULD BE 0.66975193E-00 DEG , CRIT = 0.09999999E-00

INCREMENT IN RA OF ASC NODE WOULD BE -0.29057666E-00 DEG , CRIT = C.09999999E-00

OCTAL EQUIVALENT OF LAST LINE IS 2067400000020255346273720253C742C41200664352652200732355577205553652001



Appendix B

**Graphical Representation of the Orbital Elements of the Minor Planets:  
(1) Ceres; (2) Pallas; (30) Urania; (1036) Ganymed; and (1373) 1935 QN;  
and of the Orbital Elements of Encke's Comet**

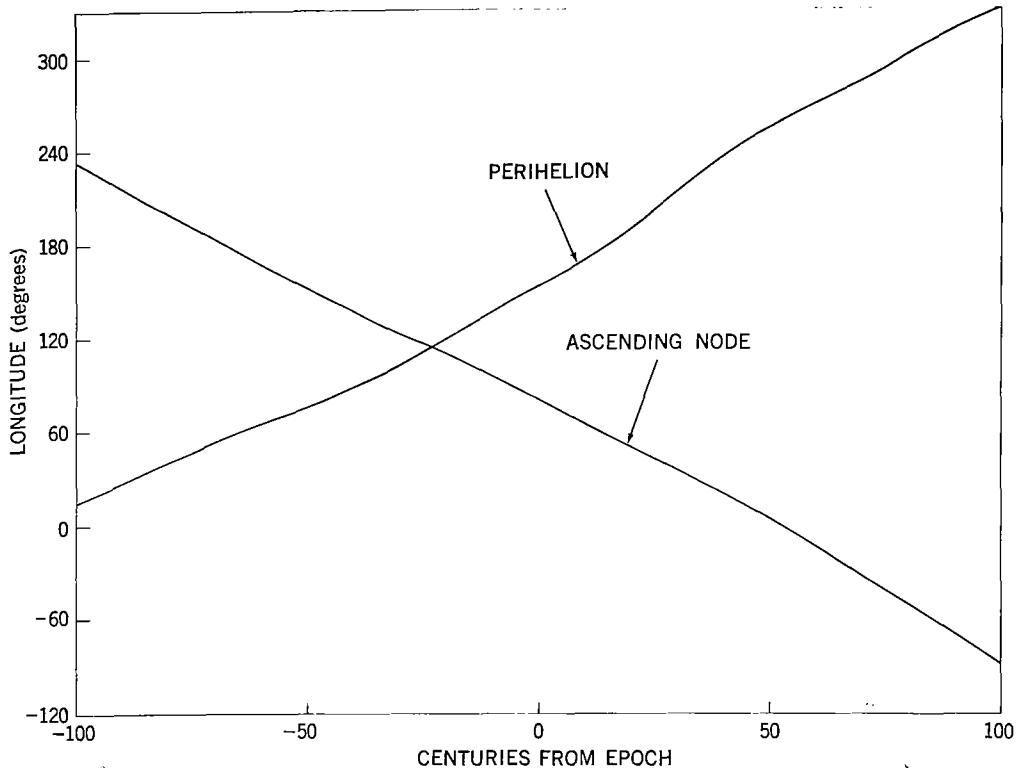


Figure B1— $\pi$  and  $\theta$  for (1) Ceres.

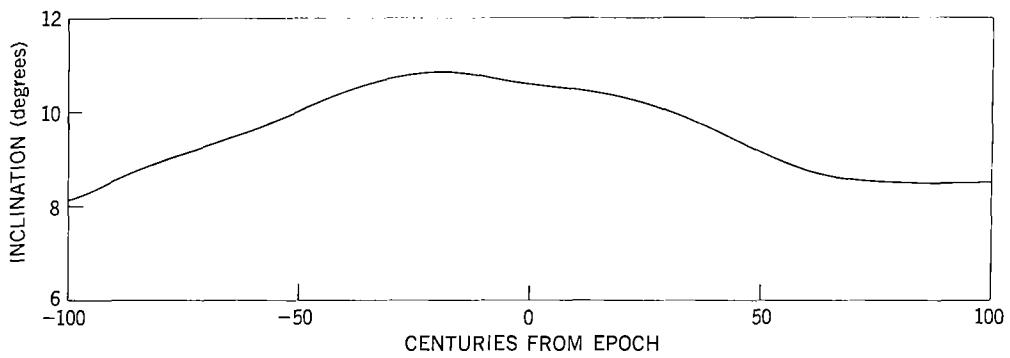


Figure B2— $i$  for (1) Ceres.

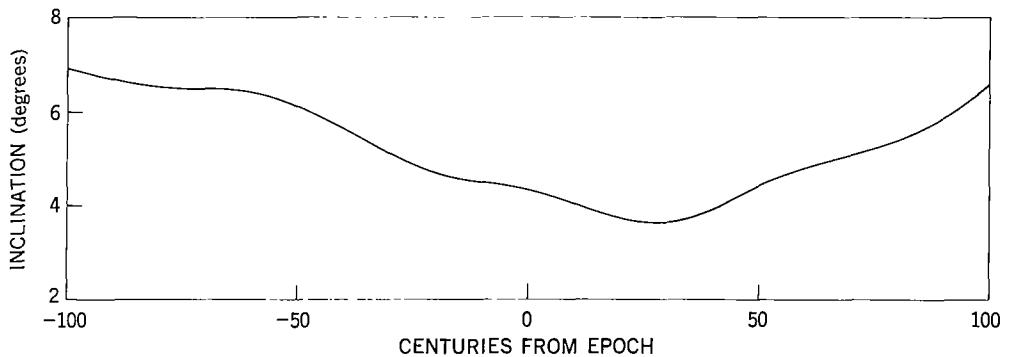


Figure B3— $e$  for (1) Ceres.

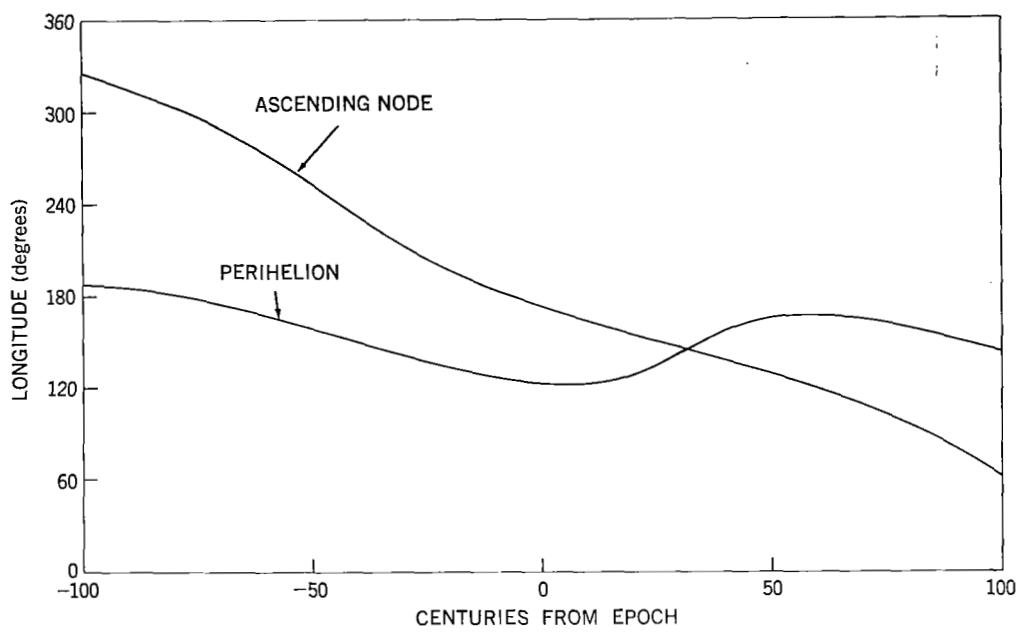


Figure B4— $\pi$  and  $\theta$  for (2) Pallas.

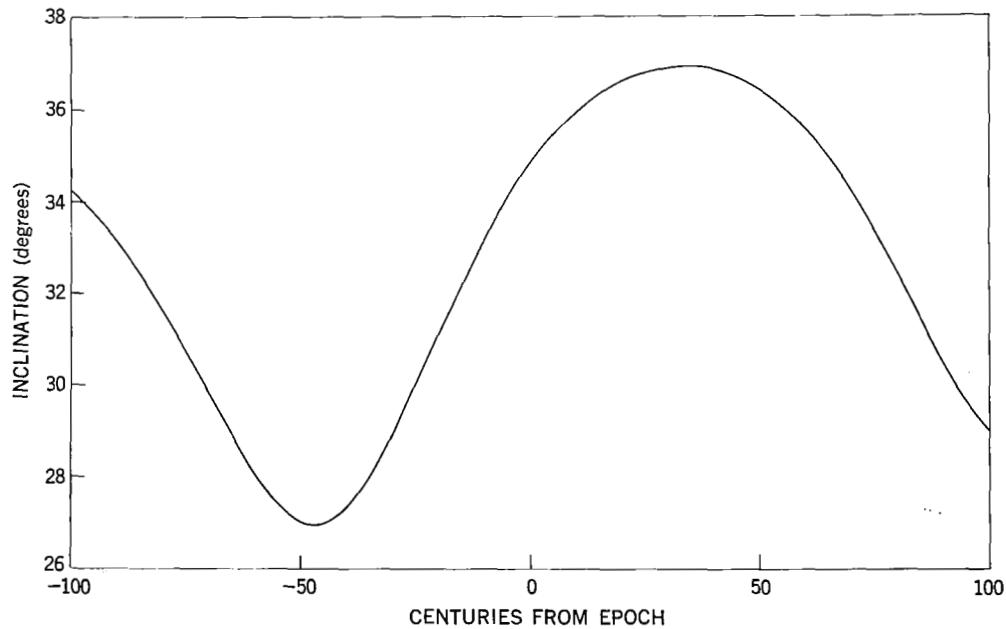
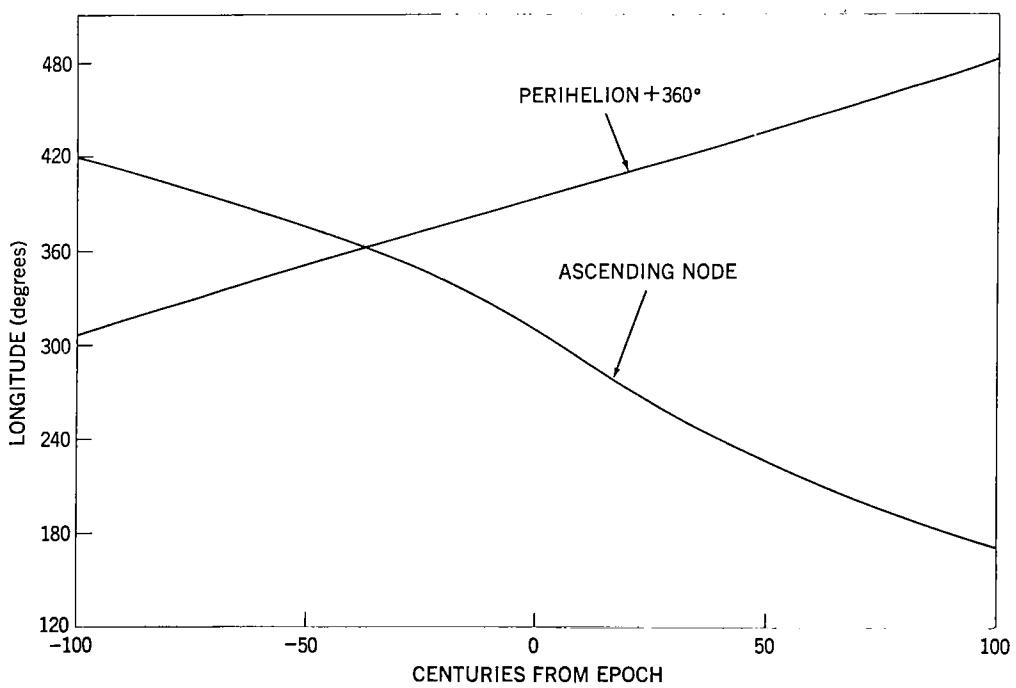
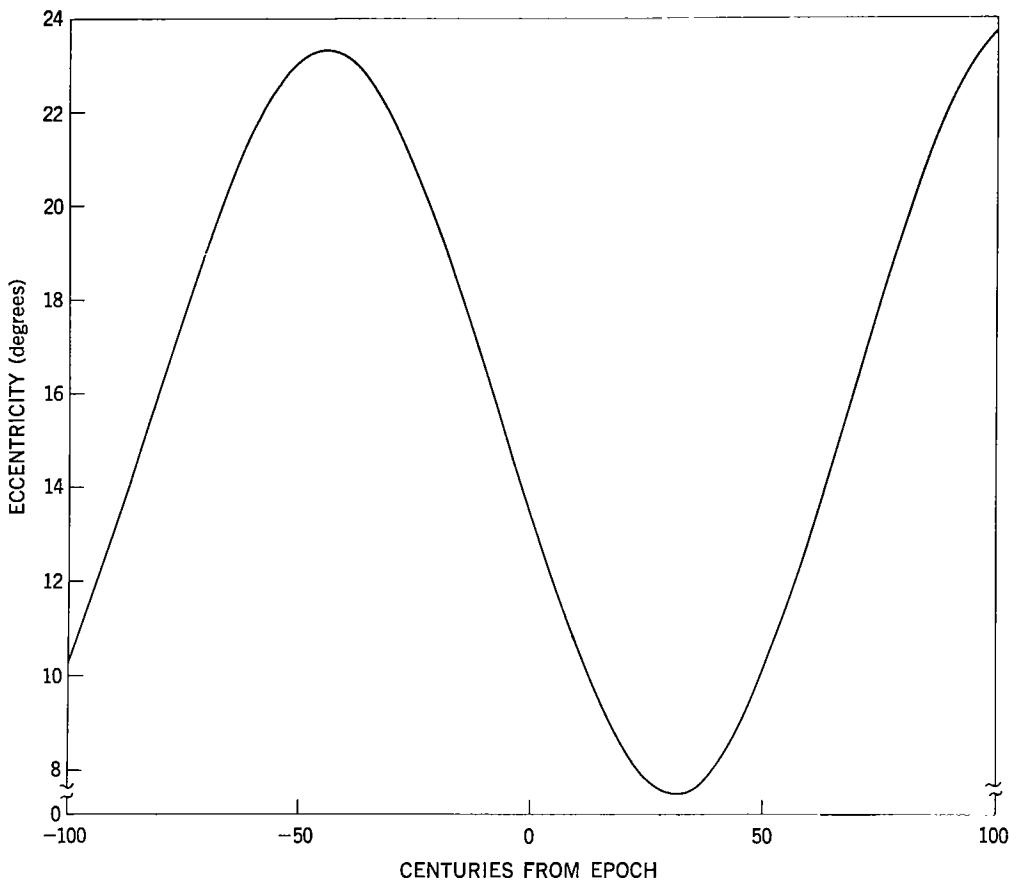


Figure B5— $i$  for (2) Pallas.



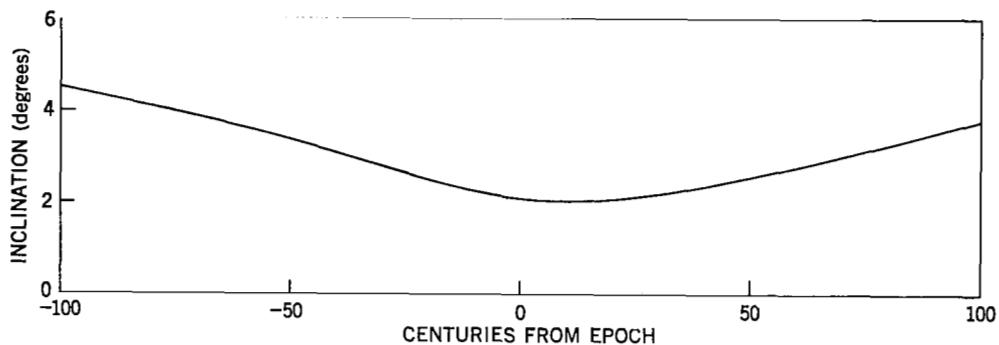


Figure B8-i for (30) Urania.

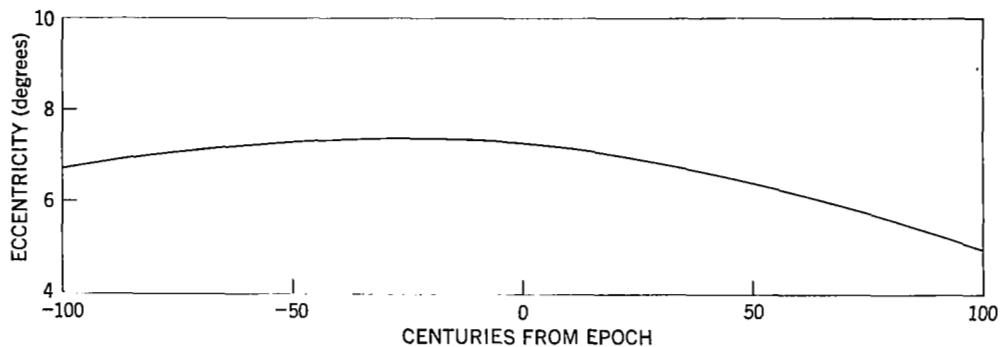


Figure B9-e for (30) Urania.

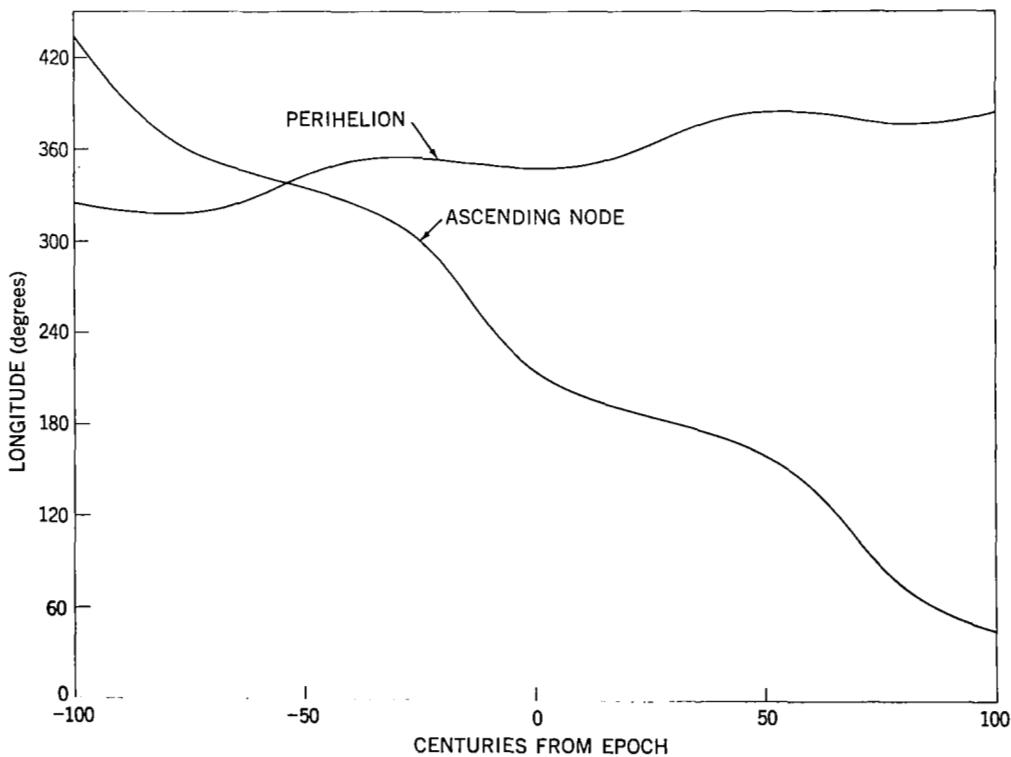


Figure B10— $\pi$  and  $\theta$  for (1036) Ganymede.

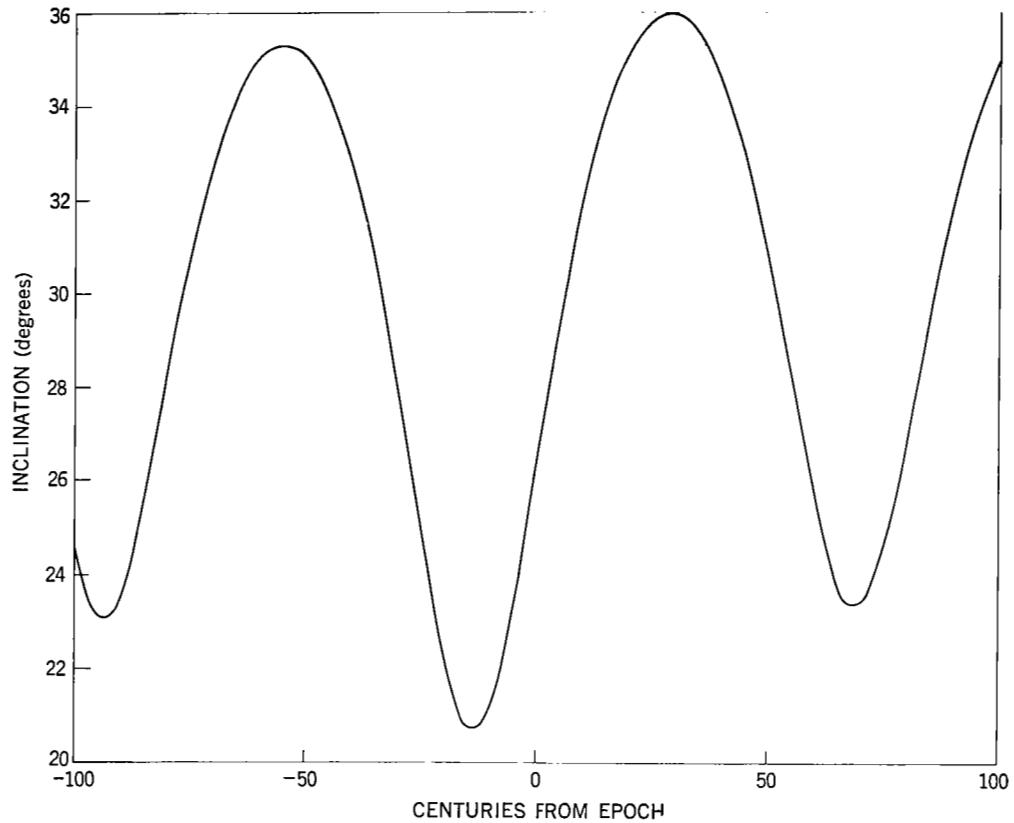


Figure B11—i for (1036) Ganymede.

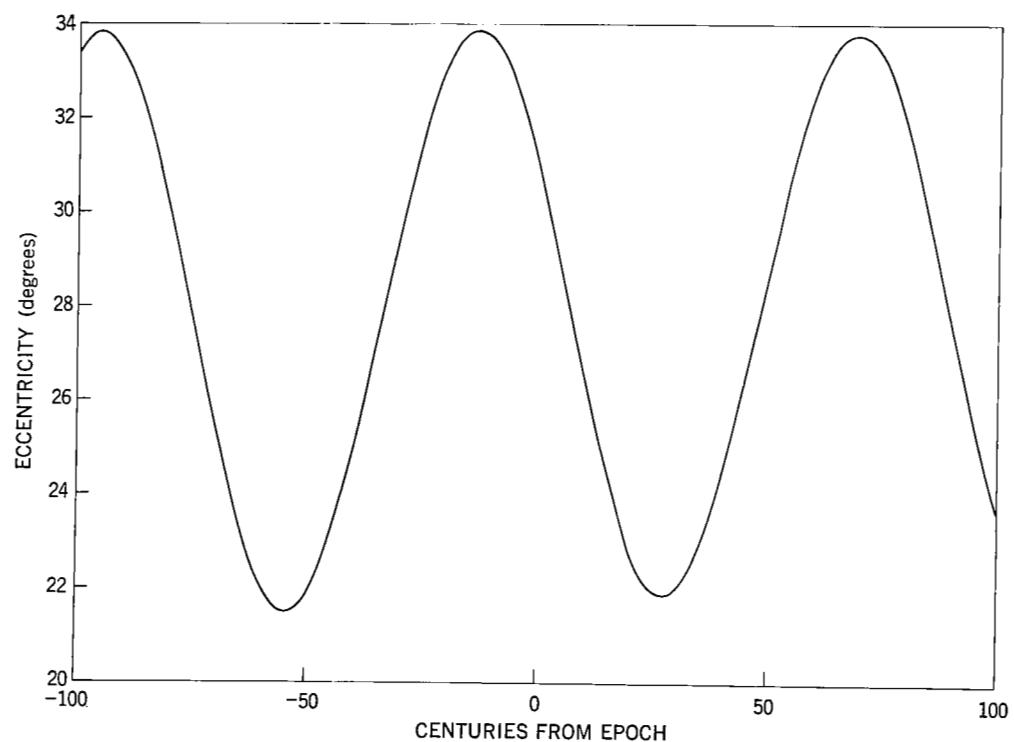


Figure B12—e for (1036) Ganymede.

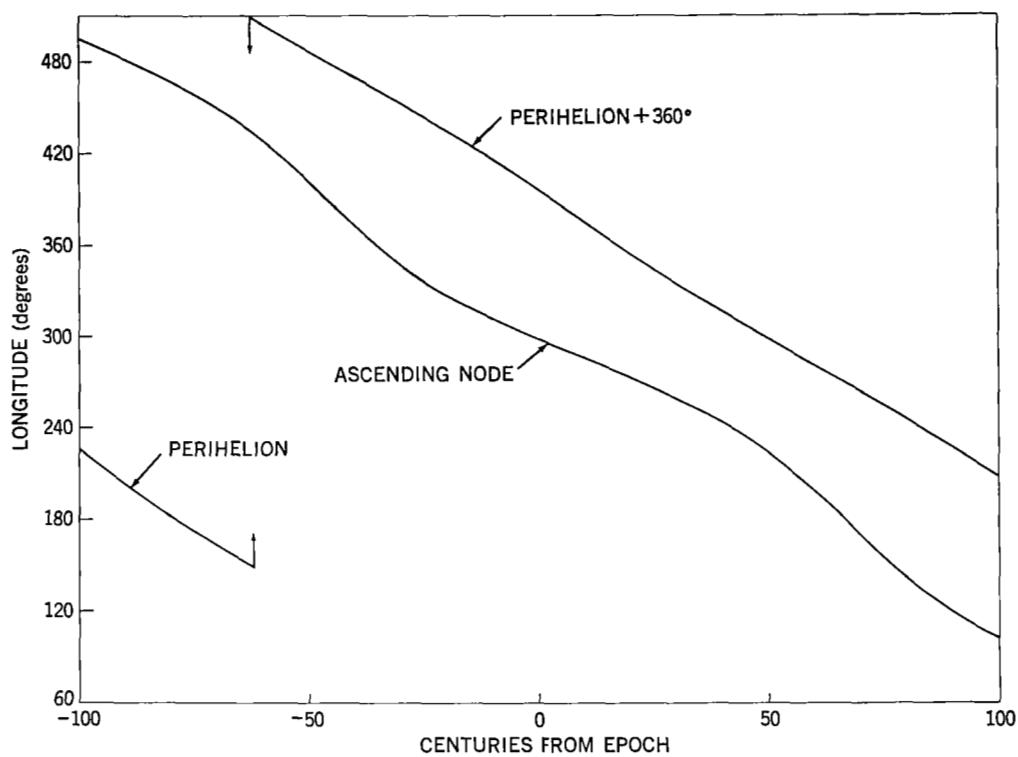


Figure B13— $\pi$  and  $\theta$  for (1373) 1935 QN.

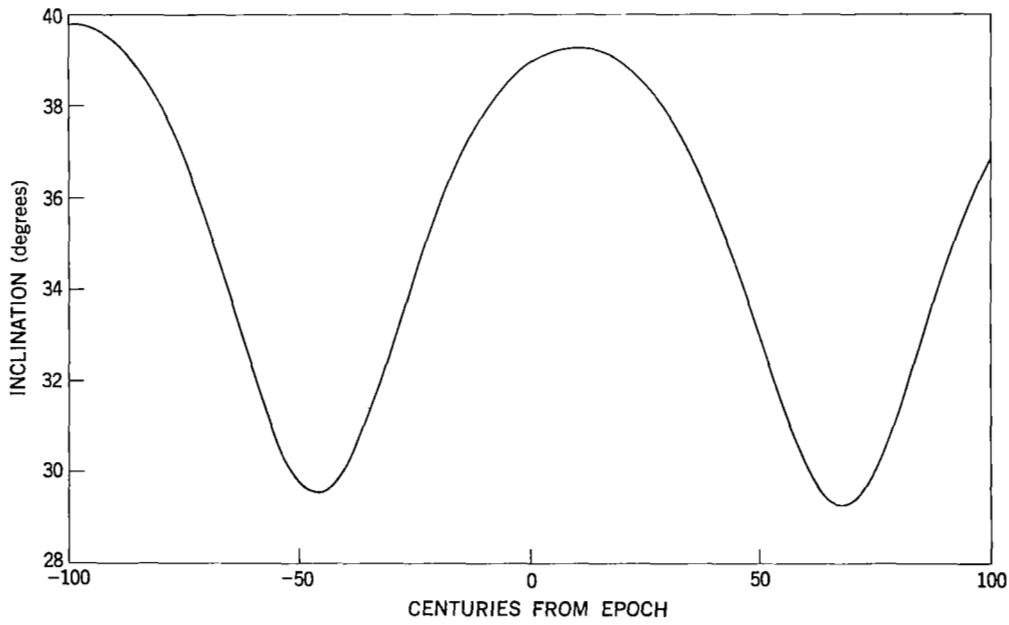
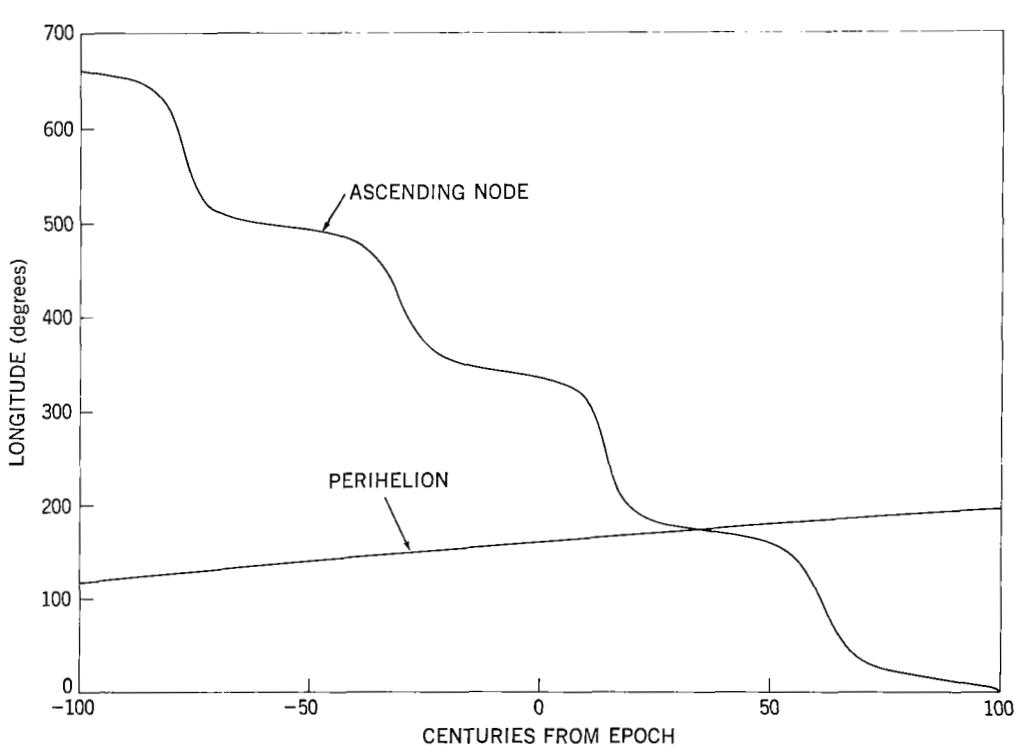
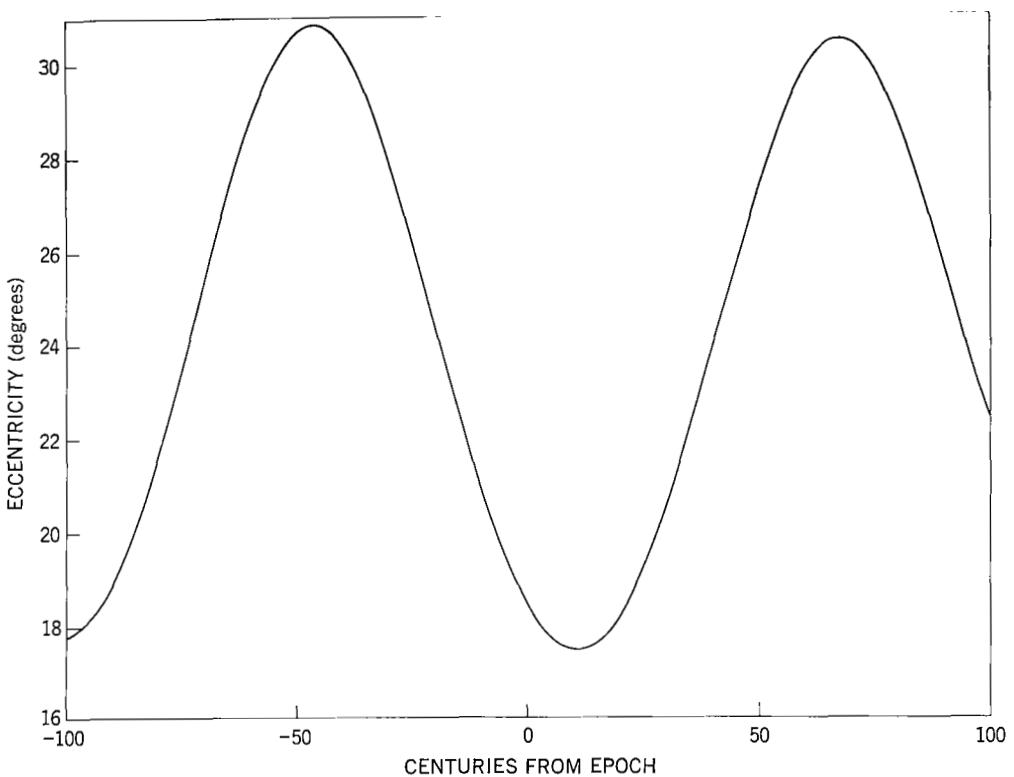


Figure B14— $i$  for (1373) 1935 QN.



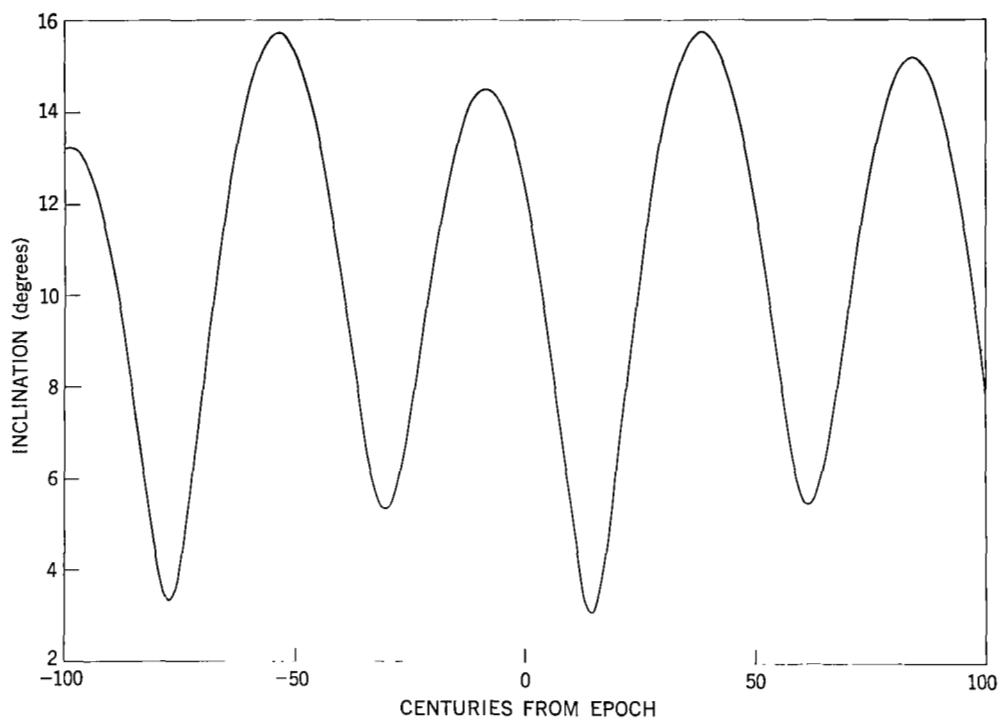


Figure B17—i for Encke's Comet.

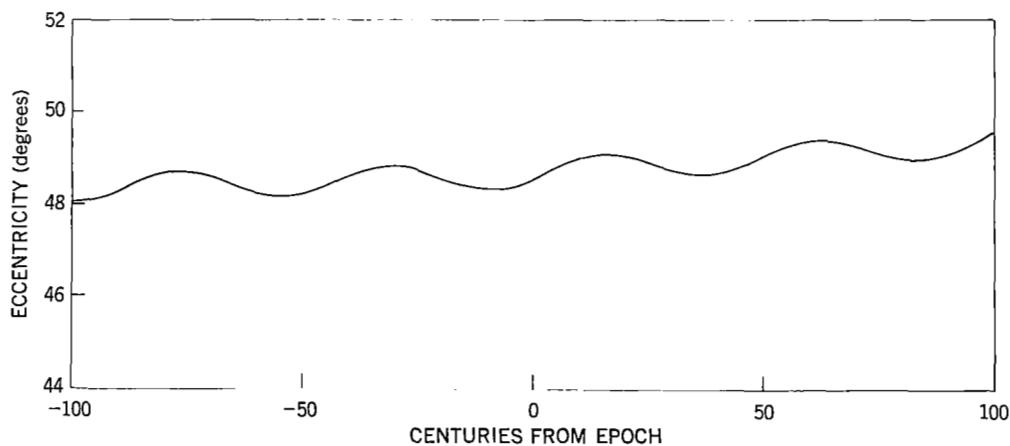


Figure B18—e for Encke's Comet.



## Appendix C

### **Numerical Results for the Minor Planets:**

**(1) Ceres; (2) Pallas; (30) Urania; (1036) Ganymede;**  
**and (1373) 1935 QN; and for Encke's Comet**

## PLANET NUMBER 1 CERES

CENTURIES FROM EPOCH	DELTA ECC (DEG)	DELTA PI (DEG)	DELTA ASC NODE (DEG)	DELTA INCL (DEG)	DELTA L (DEG)	DELTA A (AU)
-1	0.0205	-1.0009	1.4373	0.0163	1.0144	2.634E-10
-2	0.0397	-3.2036	2.9702	0.0326	3.2288	9.722E-11
-3	0.0579	-4.8106	4.4483	0.0489	4.8432	9.517E-11
-4	0.0751	-6.4240	5.9210	0.0651	6.4576	-3.098E-11
-5	0.0915	-8.0458	7.3881	0.0811	8.0721	-6.812E-11
-6	0.1072	-9.6776	8.8493	0.0968	9.6867	-3.005E-10
-7	0.1225	-11.3209	10.3042	0.1122	11.3014	-3.111E-10
-8	0.1374	-12.9768	11.7527	0.1271	12.9161	-2.957E-10
-9	0.1523	-14.6459	13.1947	0.1413	14.5310	-4.504E-10
-10	0.1674	-16.3286	14.6299	0.1549	16.1460	-6.796E-10
-11	0.1828	-18.0251	16.0585	0.1677	17.7612	-8.019E-10
-12	0.1988	-19.7349	17.4804	0.1795	19.3764	-8.962E-10
-13	0.2156	-21.4574	18.8758	0.1902	20.9918	-1.027E-09
-14	0.2335	-23.1915	20.3048	0.1998	22.6074	-9.372E-10
-15	0.2526	-24.9359	21.7077	0.2082	24.2230	-9.700E-10
-16	0.2731	-26.6889	23.1047	0.2151	25.8388	-8.855E-10
-17	0.2952	-28.4485	24.4363	0.2205	27.4547	-8.200E-10
-18	0.3191	-30.2125	25.8827	0.2242	29.0707	-7.159E-10
-19	0.3449	-31.9784	27.2646	0.2263	30.6867	-7.210E-10
-20	0.3727	-33.7436	28.6423	0.2266	32.3029	-6.289E-10
-21	0.4027	-35.5053	30.0165	0.2250	33.9190	-6.215E-10
-22	0.4349	-37.2606	31.3877	0.2215	35.5351	-6.083E-10
-23	0.4693	-39.0067	32.7566	0.2159	37.1513	-6.231E-10
-24	0.5050	-40.7407	34.1239	0.2083	38.7674	-6.822E-10
-25	0.5449	-42.4600	35.4902	0.1986	40.3834	-5.041E-10
-26	0.5861	-44.1618	36.8563	0.1868	41.9993	-5.143E-10
-27	0.6293	-45.8437	38.2228	0.1728	43.6150	-4.612E-10
-28	0.6746	-47.5034	39.5906	0.1568	45.2306	-5.439E-10
-29	0.7217	-49.1390	40.9604	0.1386	46.8460	-6.700E-10
-30	0.7706	-50.7487	42.3329	0.1182	48.4612	-5.600E-10
-31	0.8211	-52.3311	43.7089	0.0959	50.0761	-5.046E-10
-32	0.8730	-53.8848	45.0891	0.0715	51.6907	-5.086E-10
-33	0.9261	-55.4092	46.4742	0.0452	53.3050	-4.260E-10
-34	0.9802	-56.9036	47.8650	0.0169	54.9190	-2.679E-10
-35	1.0350	-58.3676	49.2620	-0.0131	56.5326	-2.752E-10
-36	1.0904	-59.8014	50.6660	-0.0448	58.1458	-1.845E-10
-37	1.1461	-61.2051	52.0776	-0.0782	59.7585	-1.937E-10
-38	1.2018	-62.5792	53.4972	-0.1130	61.3709	-2.598E-10
-39	1.2573	-63.9244	54.9255	-0.1492	62.9828	-2.598E-10
-40	1.3125	-65.2417	56.3628	-0.1866	64.5942	-1.280E-10
-41	1.3670	-66.5322	57.8096	-0.2252	66.2052	-8.119E-11
-42	1.4206	-67.7971	59.2562	-0.2547	67.8156	1.784E-11
-43	1.4731	-69.0378	60.7328	-0.3051	69.4256	1.058E-10
-44	1.5244	-70.2559	62.2096	-0.3462	71.0351	1.507E-10
-45	1.5742	-71.4531	63.6969	-0.3878	72.6441	1.043E-11
-46	1.6224	-72.6310	65.1946	-0.4298	74.2526	7.690E-11
-47	1.6687	-73.7914	66.7027	-0.4721	75.8607	-9.071E-11
-48	1.7132	-74.9361	68.2211	-0.5146	77.4682	-1.124E-10
-49	1.7555	-76.0672	69.7497	-0.5570	79.0754	-3.390E-10
-50	1.7957	-77.1864	71.2831	-0.5993	80.6820	-2.618E-10

-51	1.8336	-78.2957	72.8362	-0.6414	92.2883	-3.195E-10
-52	1.8692	-79.3970	74.3934	-0.6831	83.8942	-3.572E-10
-53	1.9023	-80.4923	75.9594	-0.7244	85.4996	-4.037E-10
-54	1.9331	-81.5834	77.5337	-0.7651	87.1047	-3.616E-10
-55	1.9614	-82.6721	79.1156	-0.8053	88.7095	-3.783E-10
-56	1.9873	-83.7603	80.7046	-0.8447	90.3140	-4.150E-10
-57	2.0108	-84.8498	82.3001	-0.8834	91.9181	-5.565E-10
-58	2.0320	-85.9422	83.9014	-0.9214	93.5221	-5.929E-10
-59	2.0509	-87.0392	85.5078	-0.9586	95.1257	-5.550E-10
-60	2.0676	-88.1423	87.1185	-0.9949	96.7292	-6.410E-10
-61	2.0822	-89.2530	88.7330	-1.0305	98.3325	-6.215E-10
-62	2.0948	-90.3726	90.3506	-1.0653	99.9357	-6.852E-10
-63	2.1059	-91.5024	91.9705	-1.0994	101.5387	-7.429E-10
-64	2.1146	-92.6435	93.5922	-1.1328	103.1416	-8.145E-10
-65	2.1222	-93.7969	95.2150	-1.1656	104.7444	-8.462E-10
-66	2.1284	-94.9634	96.8384	-1.1978	106.3471	-8.258E-10
-67	2.1334	-96.1438	98.4620	-1.2295	107.9498	-1.025E-09
-68	2.1374	-97.3386	100.0853	-1.2608	109.5524	-1.268E-09
-69	2.1407	-98.5481	101.7080	-1.2918	111.1550	-1.389E-09
-70	2.1434	-99.7726	103.3299	-1.3226	112.7576	-1.331E-09
-71	2.1456	-101.0121	104.9507	-1.3533	114.3602	-1.279E-09
-72	2.1478	-102.2664	106.5703	-1.3840	115.9628	-1.280E-09
-73	2.1499	-103.5353	108.1888	-1.4148	117.5654	-1.121E-09
-74	2.1523	-104.8181	109.8062	-1.4459	119.1680	-1.100E-09
-75	2.1551	-106.1142	111.4227	-1.4773	120.7706	-9.227E-10
-76	2.1595	-107.4227	113.0337	-1.5091	122.3732	-8.197E-10
-77	2.1626	-108.7425	114.6544	-1.5414	123.7757	-7.041E-10
-78	2.1677	-110.0724	116.2703	-1.5744	125.5783	-6.552E-10
-79	2.1738	-111.4111	117.8870	-1.6081	127.1808	-5.759E-10
-80	2.1812	-112.7571	119.5051	-1.6426	128.7633	-3.865E-10
-81	2.1898	-114.1087	121.1253	-1.6779	130.3857	-2.844E-10
-82	2.1998	-115.4644	122.7484	-1.7141	131.9880	-1.046E-10
-83	2.2113	-116.8223	124.3751	-1.7513	133.5903	5.769E-11
-84	2.2243	-118.1806	126.0065	-1.7895	135.1924	1.681E-10
-85	2.2387	-119.5370	127.6434	-1.8287	136.7944	2.307E-10
-86	2.2547	-120.8914	129.2370	-1.8688	138.3962	4.512E-10
-87	2.2721	-122.2402	130.9381	-1.9100	139.9978	6.701E-10
-88	2.2909	-123.5824	132.5979	-1.9521	141.5993	7.500E-10
-89	2.3111	-124.9163	134.2675	-1.9950	143.2005	9.567E-10
-90	2.3325	-126.2403	135.9479	-2.0388	144.8015	1.190E-09
-91	2.3550	-127.5531	137.6402	-2.0834	146.4023	1.352E-09
-92	2.3786	-128.8533	139.3456	-2.1286	148.0028	1.592E-09
-93	2.4030	-130.1393	141.0649	-2.1744	149.6030	1.740E-09
-94	2.4281	-131.4117	142.7993	-2.2205	151.2029	1.839E-09
-95	2.4537	-132.6682	144.2497	-2.2670	152.8024	2.111E-09
-96	2.4796	-133.9085	146.3170	-2.3135	154.4017	2.545E-09
-97	2.5056	-135.1323	148.1019	-2.3600	156.0006	2.721E-09
-98	2.5316	-136.3393	149.9051	-2.4063	157.5991	2.891E-09
-99	2.5573	-137.5293	151.7274	-2.4521	159.1974	3.231E-09
-100	2.5925	-139.7025	153.5690	-2.4973	160.7953	3.426E-09

## PLANET NUMBER 1 CERES

CENTURIES FROM EPOCH	DELTA ECC (DEG)	DELTA PI (DEG)	DELTA ASC NODE (DEG)	DELTA INCL (DEG)	DELTA L (DEG)	DELTA A (AU)
1	-0.0218	1.6018	-1.4913	-0.0162	-1.6144	-1.680E-10
2	-0.0448	3.2073	-2.9860	-0.0324	-3.2289	-1.431E-10
3	-0.0693	4.8195	-4.4336	-0.0484	-4.8435	-1.238E-10
4	-0.0951	6.4416	-5.9837	-0.0642	-6.4582	-1.447E-10
5	-0.1223	8.0768	-7.4856	-0.0799	-8.0730	-1.841E-10
6	-0.1508	9.7283	-8.9309	-0.0955	-9.6880	-1.672E-10
7	-0.1805	11.3997	-10.4930	-0.1110	-11.3031	-2.293E-10
8	-0.2113	13.0942	-11.9975	-0.1264	-12.9185	-2.876E-10
9	-0.2431	14.8152	-13.5019	-0.1417	-14.5340	-3.839E-10
10	-0.2756	16.5659	-15.0058	-0.1571	-16.1498	-6.811E-10
11	-0.3088	18.3496	-16.5088	-0.1726	-17.7659	-7.978E-10
12	-0.3424	20.1692	-18.0106	-0.1882	-19.3821	-7.912E-10
13	-0.3761	22.0274	-19.5109	-0.2041	-20.9987	-7.619E-10
14	-0.4097	23.9267	-21.0075	-0.2203	-22.6155	-7.327E-10
15	-0.4429	25.8692	-22.5063	-0.2369	-24.2326	-1.081E-09
16	-0.4754	27.8565	-24.0012	-0.2540	-25.8500	-1.348E-09
17	-0.5069	29.8899	-25.4942	-0.2718	-27.4677	-1.748E-09
18	-0.5370	31.9697	-26.9853	-0.2902	-29.0856	-2.022E-09
19	-0.5655	34.0961	-28.4746	-0.3095	-30.7039	-2.300E-09
20	-0.5919	36.2681	-29.9624	-0.3297	-32.3222	-2.532E-09
21	-0.6160	38.4843	-31.4489	-0.3509	-33.9408	-2.618E-09
22	-0.6374	40.7422	-32.9344	-0.3732	-35.5296	-2.843E-09
23	-0.6559	43.0387	-34.4195	-0.3966	-37.1786	-2.981E-09
24	-0.6711	45.3698	-35.9044	-0.4213	-38.7973	-3.153E-09
25	-0.6829	47.7308	-37.3899	-0.4473	-40.4171	-3.580E-09
26	-0.6909	50.1163	-38.8763	-0.4747	-42.0365	-3.836E-09
27	-0.6950	52.5202	-40.3645	-0.5035	-43.6559	-4.081E-09
28	-0.6951	54.9361	-41.8551	-0.5338	-45.2754	-4.411E-09
29	-0.6911	57.3570	-43.3488	-0.5655	-46.8949	-4.795E-09
30	-0.6829	59.7761	-44.8463	-0.5987	-48.5143	-5.087E-09
31	-0.6705	62.1862	-46.3485	-0.6334	-50.1336	-5.372E-09
32	-0.6541	64.5806	-47.8563	-0.6696	-51.7529	-5.528E-09
33	-0.6336	66.9528	-49.3703	-0.7073	-53.3720	-5.885E-09
34	-0.6093	69.2967	-50.8915	-0.7463	-54.9908	-6.050E-09
35	-0.5814	71.6070	-52.4208	-0.7867	-56.6095	-6.177E-09
36	-0.5500	73.8789	-53.9589	-0.8284	-58.2279	-6.408E-09
37	-0.5155	76.1085	-55.5067	-0.8712	-59.8460	-6.817E-09
38	-0.4780	78.2926	-57.0650	-0.9152	-61.4638	-6.977E-09
39	-0.4380	80.4289	-58.6345	-0.9601	-63.0812	-7.034E-09
40	-0.3958	82.5158	-60.2160	-1.0059	-64.6983	-7.062E-09
41	-0.3516	84.5524	-61.8102	-1.0525	-66.3149	-6.990E-09
42	-0.3058	86.5388	-63.4177	-1.0996	-67.9311	-7.080E-09
43	-0.2588	88.4754	-65.0391	-1.1472	-69.5469	-7.162E-09
44	-0.2109	90.3633	-66.6748	-1.1950	-71.1622	-7.400E-09
45	-0.1623	92.2042	-68.3252	-1.2430	-72.7770	-7.479E-09
46	-0.1135	94.0001	-69.9907	-1.2909	-74.3914	-7.368E-09
47	-0.0646	95.7533	-71.6714	-1.3386	-76.0053	-7.535E-09
48	-0.0160	97.4666	-73.3675	-1.3858	-77.6187	-7.476E-09
49	0.0320	99.1429	-75.0789	-1.4325	-79.2316	-7.603E-09
50	0.0793	100.7853	-76.8057	-1.4784	-80.8440	-7.657E-09

51	0.1257	102.3469	-78.5474	-1.5233	-82.4560	-7.744E-09
52	0.1710	103.9811	-80.3039	-1.5572	-84.0676	-7.685E-09
53	0.2150	105.5413	-82.0746	-1.6093	-85.6787	-7.845E-09
54	0.2575	107.0807	-83.8589	-1.6510	-87.2894	-8.253E-09
55	0.2986	108.6026	-85.6563	-1.6907	-88.8992	-8.365E-09
56	0.3381	110.1104	-87.4658	-1.7280	-90.5097	-8.585E-09
57	0.3761	111.0071	-89.2867	-1.7641	-92.1194	-8.577E-09
58	0.4124	113.0359	-91.1180	-1.7992	-93.7287	-8.643E-09
59	0.4471	114.5797	-92.9586	-1.8310	-95.3377	-8.801E-09
60	0.4802	116.0612	-94.8075	-1.8619	-96.9466	-9.190E-09
61	0.5119	117.5431	-96.6635	-1.9002	-98.5552	-9.412E-09
62	0.5421	119.0278	-98.5255	-1.9164	-100.1636	-9.536E-09
63	0.5711	120.5176	-100.3921	-1.9406	-101.7719	-9.683E-09
64	0.5990	122.0144	-102.2624	-1.9626	-103.3801	-9.958E-09
65	0.6258	123.5200	-104.1350	-1.9826	-104.9881	-1.003E-08
66	0.6519	125.0359	-106.0089	-2.0006	-106.5962	-1.023E-08
67	0.6773	126.5634	-107.8830	-2.0166	-108.2042	-1.067E-08
68	0.7024	128.1034	-109.7562	-2.0308	-109.8122	-1.100E-08
69	0.7273	129.6565	-111.6276	-2.0432	-111.4203	-1.138E-08
70	0.7522	131.2231	-113.4963	-2.0539	-113.0284	-1.186E-08
71	0.7775	132.8032	-115.3617	-2.0631	-114.6366	-1.241E-08
72	0.8032	134.3964	-117.2230	-2.0708	-116.2449	-1.285E-08
73	0.8298	136.0021	-119.0798	-2.0773	-117.8532	-1.325E-08
74	0.8573	137.6135	-120.9315	-2.0826	-119.4617	-1.359E-08
75	0.8861	139.2471	-122.7781	-2.0869	-121.0703	-1.408E-08
76	0.9164	140.8836	-124.6192	-2.0903	-122.6791	-1.436E-08
77	0.9483	142.5270	-126.4549	-2.0930	-124.2879	-1.462E-08
78	0.9821	144.1753	-128.2853	-2.0951	-125.8962	-1.518E-08
79	1.0179	145.8264	-130.1105	-2.0967	-127.5061	-1.569E-08
80	1.0558	147.4777	-131.9310	-2.0977	-129.1153	-1.624E-08
81	1.0960	149.1267	-133.7471	-2.0989	-130.7246	-1.672E-08
82	1.1387	150.7708	-135.5593	-2.0993	-132.3340	-1.711E-08
83	1.1837	152.4073	-137.3683	-2.1007	-133.9435	-1.750E-08
84	1.2312	154.0336	-139.1747	-2.1016	-135.5530	-1.793E-08
85	1.2812	155.6471	-140.9793	-2.1026	-137.1625	-1.831E-08
86	1.3337	157.2453	-142.7830	-2.1037	-138.7721	-1.854E-08
87	1.3866	158.8259	-144.5864	-2.1050	-140.3816	-1.898E-08
88	1.4457	160.3866	-146.3906	-2.1055	-141.9910	-1.929E-08
89	1.5051	161.9254	-148.1964	-2.1083	-143.6004	-1.977E-08
90	1.5666	163.4407	-150.0047	-2.1102	-145.2096	-2.020E-08
91	1.6299	164.9309	-151.8163	-2.1122	-146.8187	-2.060E-08
92	1.6950	166.3947	-153.6322	-2.1143	-149.4277	-2.088E-08
93	1.7617	167.8312	-155.4530	-2.1165	-150.0364	-2.124E-08
94	1.8296	169.2396	-157.2795	-2.1186	-151.6449	-2.124E-08
95	1.8986	170.6195	-159.1125	-2.1205	-153.2931	-2.147E-08
96	1.9685	171.9707	-160.9525	-2.1221	-154.8610	-2.176E-08
97	2.0389	173.2932	-162.8000	-2.1233	-156.4886	-2.200E-08
98	2.1097	174.5873	-164.6554	-2.1239	-158.0758	-2.223E-08
99	2.1806	175.8535	-166.5190	-2.1238	-159.6827	-2.236E-08
100	2.2512	177.0925	-168.3909	-2.1223	-161.2893	-2.264E-08

## PLANET NUMBER 2 PALLAS

CENTURIES FROM EPOCH	DELTA ECC (DEG)	DELTA PI (DEG)	DELTA ASC NODE (DEG)	DELTA INCL (DEG)	DELTA L (DEG)	DELTA A (AU)
-1	0.3016	0.2688	1.0288	-0.1394	0.6521	1.004E-10
-2	0.6057	0.5735	2.0715	-0.2838	1.3133	8.359E-10
-3	0.9118	0.9126	3.1290	-0.4333	1.9655	1.673E-09
-4	1.2197	1.2341	4.2019	-0.5879	2.0146	2.194E-09
-5	1.5289	1.6865	5.2310	-0.7476	3.2003	2.752E-09
-6	1.8391	2.1183	6.3971	-0.9124	3.9026	2.828E-09
-7	2.1499	2.5780	7.5209	-1.0823	4.5412	2.972E-09
-8	2.4609	3.0642	8.6634	-1.2571	5.1760	2.992E-09
-9	2.7717	3.5757	9.8254	-1.4368	5.8069	2.901E-09
-10	3.0818	4.1112	11.0076	-1.6214	6.4336	3.188E-09
-11	3.3909	4.695	12.2111	-1.8100	7.0561	2.676E-09
-12	3.6985	5.2496	13.4367	-2.0044	7.6741	2.086E-09
-13	4.0042	5.8504	14.6854	-2.2025	8.2875	1.827E-09
-14	4.3074	6.4709	15.9581	-2.4047	8.8962	1.523E-09
-15	4.6078	7.1102	17.2556	-2.6109	9.4994	1.029E-09
-16	4.9048	7.7673	18.5791	-2.8206	10.0987	4.530E-10
-17	5.1980	8.4414	19.9294	-3.0336	10.6923	1.105E-10
-18	5.4868	9.1317	21.3073	-3.2425	11.2806	-1.316E-10
-19	5.7708	9.8373	22.7140	-3.4679	11.8635	-1.372E-10
-20	6.0494	10.5975	24.1502	-3.6883	12.4410	-8.076E-10
-21	6.3221	11.2915	25.6167	-3.9103	13.0129	-1.231E-09
-22	6.5885	12.0387	27.1144	-4.1333	13.5792	-1.437E-09
-23	6.8479	12.7983	28.6441	-4.3567	14.1339	-1.839E-09
-24	7.0998	13.5696	30.2063	-4.5799	14.6948	-2.208E-09
-25	7.3438	14.3520	31.8317	-4.8022	15.2440	-2.257E-09
-26	7.5793	15.1449	33.4307	-5.0229	15.7870	-2.522E-09
-27	7.8058	15.9476	35.0938	-5.2413	16.3256	-2.763E-09
-28	8.0228	16.7595	36.7911	-5.4565	16.8579	-3.520E-09
-29	8.2298	17.5800	38.5226	-5.6677	17.3948	-3.724E-09
-30	8.4264	18.4086	40.2884	-5.8741	17.9063	-4.113E-09
-31	8.6121	19.2445	42.0830	-6.0747	18.4225	-4.460E-09
-32	8.7864	20.0874	43.9211	-6.2688	18.9337	-4.831E-09
-33	8.9489	20.9366	45.7868	-6.4554	19.4401	-5.456E-09
-34	9.0993	21.7915	47.6843	-6.6336	19.9417	-5.700E-09
-35	9.2372	22.6517	49.6123	-6.8026	20.4390	-5.927E-09
-36	9.3621	23.5165	51.5644	-6.9614	20.9321	-6.285E-09
-37	9.4739	24.3855	53.5539	-7.1093	21.4213	-6.792E-09
-38	9.5722	25.2581	55.5618	-7.2455	21.9070	-7.366E-09
-39	9.6567	26.1333	57.5570	-7.3692	22.3895	-7.671E-09
-40	9.7273	27.0120	59.6509	-7.4798	22.8691	-7.979E-09
-41	9.7838	27.8924	61.7230	-7.5766	23.3463	-8.578E-09
-42	9.8260	28.7743	63.8104	-7.6593	23.8213	-8.861E-09
-43	9.8538	29.6572	65.9100	-7.7273	24.2146	-9.365E-09
-44	9.8671	30.5407	68.0187	-7.7803	24.7665	-9.932E-09
-45	9.8659	31.4243	70.1331	-7.8181	25.2376	-1.038E-08
-46	9.8503	32.3074	72.2501	-7.8406	25.7081	-1.085E-08
-47	9.8202	33.1896	74.3661	-7.9479	26.1786	-1.179E-08
-48	9.7758	34.0704	76.4779	-7.8397	26.6493	-1.243E-08
-49	9.7171	34.9493	78.5822	-7.9166	27.1207	-1.326E-08
-50	9.6443	35.8258	80.6757	-7.7788	27.5933	-1.324E-08

-51	9.5576	36.6995	82.7555	-7.7267	28.0673	-1.392E-08
-52	9.4573	37.5697	84.8185	-7.6607	28.5431	-1.442E-08
-53	9.3436	38.4362	86.8621	-7.5814	29.0211	-1.507E-08
-54	9.2168	39.2983	88.8839	-7.4895	29.5017	-1.540E-08
-55	9.0771	40.1556	90.8815	-7.3856	29.9851	-1.625E-08
-56	8.9251	41.0076	92.8529	-7.2705	30.4716	-1.683E-08
-57	8.7610	41.8538	94.7964	-7.1450	30.9615	-1.755E-08
-58	8.5852	42.6938	96.7105	-7.0099	31.4550	-1.812E-08
-59	8.3983	43.5271	98.5936	-6.8661	31.9529	-1.845E-08
-60	8.2005	44.3531	100.4455	-6.7143	32.4539	-1.900E-08
-61	7.9924	45.1713	102.2647	-6.5555	32.9596	-1.945E-08
-62	7.7745	45.9813	104.0509	-6.3902	33.4697	-1.991E-08
-63	7.5472	46.7826	105.8038	-6.2200	33.9843	-2.053E-08
-64	7.3111	47.5746	107.5231	-6.0450	34.5035	-2.099E-08
-65	7.0666	48.3569	109.2089	-5.8662	35.0274	-2.165E-08
-66	6.8144	49.1288	110.8614	-5.6843	35.5560	-2.235E-08
-67	6.5548	49.8899	112.4809	-5.5000	36.0844	-2.326E-08
-68	6.2884	50.6396	114.0678	-5.3141	36.6276	-2.364E-08
-69	6.0157	51.3774	115.6228	-5.1271	37.1705	-2.449E-08
-70	5.7373	52.1027	117.1463	-4.9347	37.7181	-2.518E-08
-71	5.4537	52.8148	118.6392	-4.7524	38.2705	-2.594E-08
-72	5.1653	53.5133	120.1621	-4.5657	38.8275	-2.647E-08
-73	4.8727	54.2193	121.5361	-4.3800	39.3890	-2.702E-08
-74	4.5764	54.8664	122.9417	-4.1958	39.9551	-2.835E-08
-75	4.2768	55.5198	124.3201	-4.0135	40.5256	-2.919E-08
-76	3.9744	56.1569	125.6720	-3.8334	41.1003	-2.994E-08
-77	3.6697	56.7768	126.9985	-3.6559	41.6792	-3.063E-08
-78	3.3631	57.3788	128.3003	-3.4811	42.2622	-3.102E-08
-79	3.0550	57.9621	129.5785	-3.3093	42.8491	-3.136E-08
-80	2.7460	58.5259	130.8340	-3.1407	43.4399	-3.171E-08
-81	2.4363	59.0692	132.0676	-2.9755	44.0343	-3.272E-08
-82	2.1263	59.5911	133.2803	-2.8139	44.6323	-3.380E-08
-83	1.8165	60.0907	134.4729	-2.6559	45.2337	-3.437E-08
-84	1.5073	60.5669	135.6462	-2.5017	45.8384	-3.514E-08
-85	1.1989	61.0185	136.8012	-2.3513	46.4462	-3.579E-08
-86	0.8917	61.4444	137.9386	-2.2048	47.0571	-3.672E-08
-87	0.5861	61.8433	139.0592	-2.0621	47.6702	-3.738E-08
-88	0.2824	62.2140	140.1638	-1.9235	48.2873	-3.810E-08
-89	-0.0191	62.5549	141.2531	-1.7887	48.9065	-3.829E-08
-90	-0.3182	62.8647	142.3278	-1.6579	49.5281	-3.878E-08
-91	-0.6145	63.1418	143.3886	-1.5311	50.1522	-3.931E-08
-92	-0.9077	63.3844	144.4362	-1.4081	50.7785	-3.928E-08
-93	-1.1975	63.5909	145.4712	-1.2889	51.4069	-3.974E-08
-94	-1.4837	63.7593	146.4942	-1.1736	52.0374	-3.995E-08
-95	-1.7660	63.8878	147.5058	-1.0621	52.6699	-4.087E-08
-96	-2.0440	63.9742	148.5067	-0.9542	53.3041	-4.086E-08
-97	-2.3176	64.0163	149.4973	-0.8500	53.9401	-4.093E-08
-98	-2.5864	64.0120	150.4781	-0.7494	54.5778	-4.135E-08
-99	-2.8502	63.9589	151.4498	-0.6523	55.2169	-4.199E-08
-100	-3.1087	63.8544	152.4127	-0.5587	55.8576	-4.232E-08

## PLANET NUMBER 2 PALLAS

CENTURIES FROM EPOCH	DELTA ECC (DEG)	DELTA PI (DEG)	DELTA ASC NODE (DEG)	DELTA INCL (DEG)	DELTA L (DEG)	DELTA A (AU)
1	-0.2988	-0.2308	-1.0154	0.1343	-0.6608	-5.463E-10
2	-0.5945	-0.4216	-2.0182	0.2636	-1.3241	-7.959E-10
3	-0.8867	-0.5704	-3.0090	0.3880	-1.9899	-7.866E-10
4	-1.1750	-0.6748	-3.9884	0.5075	-2.6579	-6.741E-10
5	-1.4592	-0.7326	-4.9569	0.6222	-3.3281	-6.753E-10
6	-1.7388	-0.7412	-5.9152	0.7321	-4.0003	-1.960E-10
7	-2.0134	-0.6982	-6.8638	0.8373	-4.6745	-1.671E-10
8	-2.2828	-0.6010	-7.8033	0.9380	-5.3504	-1.195E-10
9	-2.5464	-0.4468	-8.7341	1.0340	-6.0279	8.219E-12
10	-2.8040	-0.2329	-9.6668	1.1256	-6.7070	-9.729E-10
11	-3.0551	0.0435	-10.5718	1.2128	-7.3876	-1.744E-09
12	-3.2993	0.3851	-11.4796	1.2957	-8.0695	-2.148E-09
13	-3.5360	0.7946	-12.3807	1.3743	-8.7526	-3.158E-09
14	-3.7649	1.2748	-13.2754	1.4488	-9.4368	-4.479E-09
15	-3.9855	1.8279	-14.1642	1.5191	-10.1222	-5.673E-09
16	-4.1972	2.4563	-15.0475	1.5854	-10.8084	-5.912E-09
17	-4.3995	3.1619	-15.9258	1.6477	-11.4955	-5.883E-09
18	-4.5919	3.9461	-16.7993	1.7061	-12.1835	-5.138E-09
19	-4.7737	4.8099	-17.6684	1.7606	-12.8721	-4.644E-09
20	-4.9444	5.7537	-18.5336	1.8113	-13.5613	-4.859E-09
21	-5.1034	6.7769	-19.3952	1.8583	-14.2511	-5.810E-09
22	-5.2501	7.8784	-20.2535	1.9016	-14.9413	-6.673E-09
23	-5.3839	9.0557	-21.1089	1.9412	-15.6319	-7.625E-09
24	-5.5041	10.3056	-21.9617	1.9771	-16.3229	-8.284E-09
25	-5.6103	11.6234	-22.8122	2.0095	-17.0141	-8.202E-09
26	-5.7018	13.0035	-23.6608	2.0383	-17.7055	-8.178E-09
27	-5.7782	14.4388	-24.5078	2.0635	-18.3970	-8.964E-09
28	-5.8391	15.9214	-25.3535	2.0852	-19.0885	-9.178E-09
29	-5.8840	17.4421	-26.1982	2.1035	-19.7801	-1.044E-08
30	-5.9127	18.9908	-27.0423	2.1182	-20.4715	-1.139E-08
31	-5.9249	20.5570	-27.8860	2.1294	-21.1628	-1.167E-08
32	-5.9205	22.1295	-28.7297	2.1371	-21.8539	-1.138E-08
33	-5.8995	23.6970	-29.5736	2.1414	-22.5447	-1.158E-08
34	-5.8620	25.2485	-30.4182	2.1421	-23.2352	-1.257E-08
35	-5.8081	26.7732	-31.2636	2.1393	-23.9252	-1.337E-08
36	-5.7381	28.2611	-32.1103	2.1330	-24.6148	-1.435E-08
37	-5.6522	29.7030	-32.9585	2.1231	-25.3039	-1.445E-08
38	-5.5509	31.0908	-33.8086	2.1096	-25.9923	-1.408E-08
39	-5.4347	32.4174	-34.6609	2.0925	-26.6801	-1.375E-08
40	-5.3039	33.6772	-35.5158	2.0718	-27.3672	-1.366E-08
41	-5.1592	34.8653	-36.3735	2.0473	-28.0534	-1.374E-08
42	-5.0012	35.9785	-37.2345	2.0191	-28.7387	-1.486E-08
43	-4.8303	37.0143	-38.0990	1.9871	-29.4232	-1.512E-08
44	-4.6472	37.9714	-38.9675	1.9513	-30.1065	-1.500E-08
45	-4.4524	38.8493	-39.8403	1.9116	-30.7888	-1.463E-08
46	-4.2466	39.6483	-40.7179	1.8679	-31.4699	-1.385E-08
47	-4.0303	40.3693	-41.6005	1.8202	-32.1498	-1.361E-08
48	-3.8041	41.0137	-42.4886	1.7683	-32.8283	-1.324E-08
49	-3.5684	41.5834	-43.3827	1.7124	-33.5054	-1.329E-08
50	-3.3239	42.0807	-44.2831	1.6522	-34.1810	-1.290E-08

51	-3.0710	42.5079	-45.1904	1.5877	-34.8549	-1.310E-08
52	-2.8102	42.8675	-46.1049	1.5188	-35.5272	-1.277E-08
53	-2.5419	43.1625	-47.0271	1.4454	-36.1977	-1.308E-08
54	-2.2667	43.3954	-47.9576	1.3676	-36.8664	-1.218E-08
55	-1.9849	43.5690	-48.8968	1.2851	-37.5330	-1.153E-08
56	-1.6970	43.6860	-49.8453	1.1980	-38.1976	-1.111E-08
57	-1.4034	43.7492	-50.8037	1.1061	-38.8000	-1.035E-08
58	-1.1045	43.7611	-51.7724	1.0095	-39.5201	-9.552E-09
59	-0.8007	43.7243	-52.7521	0.9079	-40.1777	-8.364E-09
60	-0.4924	43.6411	-53.7434	0.8015	-40.8329	-8.498E-09
61	-0.1800	43.5139	-54.7469	0.6900	-41.4855	-7.919E-09
62	0.1361	43.3450	-55.7633	0.5736	-42.1353	-8.163E-09
63	0.4555	43.1363	-56.7932	0.4521	-42.7822	-7.627E-09
64	0.7777	42.8901	-57.8374	0.3255	-43.4262	-6.865E-09
65	1.1025	42.6080	-58.8765	0.1938	-44.0670	-5.274E-09
66	1.4294	42.2920	-59.9713	0.0570	-44.7047	-5.548E-09
67	1.7579	41.9437	-61.0626	-0.0843	-45.3390	-5.541E-09
68	2.0876	41.5647	-62.1712	-0.2317	-45.9699	-5.423E-09
69	2.4181	41.1566	-63.2978	-0.3835	-46.5971	-4.874E-09
70	2.7489	40.7209	-64.4433	-0.5403	-47.2208	-4.676E-09
71	3.0796	40.2588	-65.6086	-0.7018	-47.8406	-4.325E-09
72	3.4097	39.7710	-66.7944	-0.8681	-48.4565	-3.860E-09
73	3.7387	39.2606	-68.0017	-1.0388	-49.0684	-3.179E-09
74	4.0661	38.7269	-69.2313	-1.2139	-49.6762	-2.492E-09
75	4.3914	38.1717	-70.4842	-1.3932	-50.2798	-1.962E-09
76	4.7141	37.5960	-71.7612	-1.5763	-50.8792	-1.011E-09
77	5.0336	37.0007	-73.0532	-1.7631	-51.4742	-5.008E-10
78	5.3494	36.3868	-74.3411	-1.9531	-52.0449	4.556E-11
79	5.6609	35.7552	-75.7457	-2.1460	-52.6511	5.273E-10
80	5.9676	35.1069	-77.1279	-2.3414	-53.2328	1.085E-09
81	6.2689	34.4425	-78.5385	-2.5390	-53.8101	1.558E-09
82	6.5642	33.7630	-79.9782	-2.7381	-54.3828	2.227E-09
83	6.8530	33.0692	-81.4478	-2.9382	-54.9511	2.814E-09
84	7.1347	32.3616	-82.9478	-3.1388	-55.5150	3.277E-09
85	7.4086	31.6412	-84.4788	-3.3393	-56.0745	4.256E-09
86	7.6743	30.9086	-86.0412	-3.5389	-56.6297	4.953E-09
87	7.9311	30.1645	-87.6356	-3.7370	-57.1808	5.467E-09
88	8.1785	29.4096	-89.2619	-3.9329	-57.7277	5.979E-09
89	8.4160	28.6445	-90.9204	-4.1258	-58.2707	6.351E-09
90	8.6429	27.8699	-92.6109	-4.3149	-58.8100	7.044E-09
91	8.8587	27.0865	-94.3332	-4.4993	-59.3456	7.455E-09
92	9.0630	26.2948	-96.0869	-4.6783	-59.9780	8.188E-09
93	9.2553	25.4955	-97.8713	-4.8509	-60.4072	8.688E-09
94	9.4350	24.6892	-99.6856	-5.0164	-60.9335	9.060E-09
95	9.6018	23.8766	-101.5288	-5.1739	-61.4573	9.364E-09
96	9.7552	23.0582	-103.3994	-5.3226	-61.9787	9.664E-09
97	9.8948	22.2347	-105.2961	-5.4617	-62.4983	1.026E-08
98	10.0203	21.4067	-107.2169	-5.5903	-63.0162	1.070E-08
99	10.1313	20.5747	-109.1600	-5.7079	-63.5328	1.122E-08
100	10.2277	19.7394	-111.1231	-5.8138	-64.0485	1.174E-08

## PLANET NUMBER 30 URANIA

CENTURIES FROM EPOCH	DELTA ECC (DEG)	DELTA PI (DEG)	DELTA ASC NODE (DEG)	DELTA INCL (DEG)	DELTA L (DEG)	DELTA A (AU)
-1	0.0090	-0.8308	1.8015	0.0126	1.2120	1.603E-10
-2	0.0176	-1.6615	3.5878	0.0261	2.4239	2.520E-10
-3	0.0257	-2.4923	5.3578	0.0407	3.6359	3.690E-10
-4	0.0334	-3.3231	7.1102	0.0563	4.8479	5.079E-10
-5	0.0407	-4.1542	8.8440	0.0729	6.0599	5.759E-10
-6	0.0476	-4.9855	10.5582	0.0903	7.2719	7.039E-10
-7	0.0540	-5.8172	12.2519	0.1087	8.4839	7.490E-10
-8	0.0601	-6.6493	13.9244	0.1280	9.6960	7.810E-10
-9	0.0657	-7.4819	15.5750	0.1481	10.9081	8.161E-10
-10	0.0709	-8.3150	17.2032	0.1690	12.1202	8.053E-10
-11	0.0757	-9.1488	18.8087	0.1907	13.3323	9.725E-10
-12	0.0800	-9.9833	20.3910	0.2131	14.5444	1.052E-09
-13	0.0840	-10.8186	21.9499	0.2362	15.7566	1.118E-09
-14	0.0876	-11.6547	23.4854	0.2600	16.9688	1.118E-09
-15	0.0907	-12.4918	24.9974	0.2944	18.1811	1.156E-09
-16	0.0935	-13.3298	26.4859	0.3094	19.3934	1.190E-09
-17	0.0959	-14.1688	27.9511	0.3349	20.6057	1.274E-09
-18	0.0979	-15.0090	29.3932	0.3609	21.8181	1.378E-09
-19	0.0995	-15.8503	30.8125	0.3874	23.0305	1.424E-09
-20	0.1008	-16.6928	32.2092	0.4143	24.2429	1.511E-09
-21	0.1017	-17.5365	33.5838	0.4416	25.4554	1.560E-09
-22	0.1022	-18.3816	34.9367	0.4692	26.6679	1.714E-09
-23	0.1024	-19.2280	36.2684	0.4971	27.8805	1.734E-09
-24	0.1023	-20.0758	37.5793	0.5254	29.0932	1.838E-09
-25	0.1019	-20.9250	38.8700	0.5538	30.3059	1.908E-09
-26	0.1011	-21.7757	40.1411	0.5825	31.5186	1.959E-09
-27	0.1000	-22.6279	41.3931	0.6114	32.7314	2.107E-09
-28	0.0986	-23.4816	42.6267	0.6403	33.9443	2.146E-09
-29	0.0969	-24.3368	43.8424	0.6694	35.1572	2.232E-09
-30	0.0949	-25.1936	45.0410	0.6986	36.3702	2.394E-09
-31	0.0926	-26.0519	46.2229	0.7279	37.5832	2.504E-09
-32	0.0901	-26.9118	47.3889	0.7571	38.7964	2.671E-09
-33	0.0872	-27.7734	48.5395	0.7864	40.0095	2.787E-09
-34	0.0842	-28.6365	49.6755	0.8157	41.2228	2.947E-09
-35	0.0809	-29.5012	50.7973	0.8449	42.4361	3.110E-09
-36	0.0773	-30.3676	51.9057	0.8740	43.6495	3.200E-09
-37	0.0735	-31.2355	53.0013	0.9031	44.8629	3.334E-09
-38	0.0695	-32.1050	54.0845	0.9320	46.0765	3.452E-09
-39	0.0653	-32.9761	55.1562	0.9609	47.2901	3.710E-09
-40	0.0609	-33.8488	56.2167	0.9896	48.5037	3.772E-09
-41	0.0562	-34.7230	57.2667	1.0181	49.7175	3.894E-09
-42	0.0514	-35.5987	58.3066	1.0465	50.9313	4.018E-09
-43	0.0463	-36.4760	59.3371	1.0747	52.1453	4.217E-09
-44	0.0411	-37.3547	60.3587	1.1028	53.3523	4.387E-09
-45	0.0357	-38.2349	61.3718	1.1306	54.5733	4.580E-09
-46	0.0301	-39.1165	62.3769	1.1583	55.7875	4.752E-09
-47	0.0244	-39.9996	63.3744	1.1857	57.0019	4.913E-09
-48	0.0184	-40.8840	64.3049	1.2130	58.2161	5.161E-09
-49	0.0123	-41.7698	65.3486	1.2400	59.4305	5.359E-09
-50	0.0061	-42.6568	66.3261	1.2668	60.6450	5.498E-09

-51	-0.0004	-43.5452	67.2977	1.2934	61.8596	5.620E-09
-52	-0.0070	-44.4348	68.2638	1.3198	63.0743	5.721E-09
-53	-0.0137	-45.3257	69.2246	1.3459	64.2891	5.876E-09
-54	-0.0206	-46.2178	70.1806	1.3719	65.5040	6.062E-09
-55	-0.0277	-47.1110	71.1319	1.3976	66.7189	6.080E-09
-56	-0.0349	-48.0053	72.0790	1.4231	67.9340	6.254E-09
-57	-0.0423	-48.9008	73.0220	1.4485	69.1491	6.350E-09
-58	-0.0498	-49.7973	73.9613	1.4736	70.3644	6.476E-09
-59	-0.0576	-50.6949	74.8969	1.4985	71.5797	6.685E-09
-60	-0.0654	-51.5936	75.3292	1.5232	72.7952	6.866E-09
-61	-0.0735	-52.4933	76.7582	1.5478	74.0107	7.089E-09
-62	-0.0817	-53.3939	77.6842	1.5722	75.2264	7.265E-09
-63	-0.0901	-54.2956	78.6073	1.5964	76.4421	7.301E-09
-64	-0.0986	-55.1982	79.5277	1.6204	77.6530	7.464E-09
-65	-0.1073	-56.1018	80.4454	1.6443	78.8739	7.587E-09
-66	-0.1163	-57.0063	81.3605	1.6681	80.0900	7.819E-09
-67	-0.1254	-57.9118	82.2731	1.6917	81.3061	7.903E-09
-68	-0.1347	-58.8183	83.1833	1.7152	82.5224	8.059E-09
-69	-0.1442	-59.7257	84.0911	1.7385	83.7333	8.139E-09
-70	-0.1538	-60.6341	84.9966	1.7618	84.9553	8.287E-09
-71	-0.1637	-61.5435	85.8997	1.7849	86.1719	8.473E-09
-72	-0.1738	-62.4539	86.8004	1.8080	87.3886	8.564E-09
-73	-0.1842	-63.3654	87.6988	1.8309	88.6054	8.712E-09
-74	-0.1947	-64.2779	88.5949	1.8538	89.8223	8.857E-09
-75	-0.2055	-65.1914	89.4885	1.8766	91.0393	9.051E-09
-76	-0.2165	-66.1062	90.3797	1.8993	92.2565	9.218E-09
-77	-0.2277	-67.0220	91.2683	1.9220	93.4737	9.369E-09
-78	-0.2391	-67.9391	92.1544	1.9446	94.6911	9.414E-09
-79	-0.2508	-68.8575	93.0378	1.9672	95.9086	9.589E-09
-80	-0.2628	-69.7771	93.9186	1.9986	97.1262	9.723E-09
-81	-0.2750	-70.6981	94.7965	2.0121	98.3440	9.933E-09
-82	-0.2874	-71.6206	95.6716	2.0345	99.5618	1.014E-08
-83	-0.3001	-72.5445	96.5436	2.0568	100.7798	1.026E-08
-84	-0.3131	-73.4700	97.4126	2.0791	101.9979	1.048E-08
-85	-0.3263	-74.3972	98.2784	2.1014	103.2161	1.058E-08
-86	-0.3397	-75.3260	99.1410	2.1236	104.4345	1.081E-08
-87	-0.3534	-76.2567	100.0002	2.1457	105.6529	1.086E-08
-88	-0.3674	-77.1892	100.8560	2.1679	106.8715	1.104E-08
-89	-0.3817	-78.1236	101.7082	2.1899	108.0902	1.123E-08
-90	-0.3962	-79.0602	102.5567	2.2119	109.3091	1.139E-08
-91	-0.4109	-79.9988	103.4015	2.2338	110.5281	1.155E-08
-92	-0.4260	-80.9397	104.2425	2.2557	111.7472	1.164E-08
-93	-0.4412	-81.8829	105.0796	2.2774	112.9664	1.180E-08
-94	-0.4567	-82.8286	105.9126	2.2991	114.1858	1.195E-08
-95	-0.4725	-83.7767	106.7417	2.3207	115.4053	1.212E-08
-96	-0.4885	-84.7275	107.5666	2.3422	116.6250	1.223E-08
-97	-0.5048	-85.6810	108.3873	2.3635	117.8447	1.236E-08
-98	-0.5213	-86.6373	109.2038	2.3847	119.0647	1.253E-08
-99	-0.5380	-87.5965	110.0160	2.4058	120.2847	1.268E-08
-100	-0.5549	-88.5586	110.8238	2.4268	121.5049	1.280E-08

## PLANET NUMBER 30 URANIA

CENTURIES FROM EPOCH	DELTA ECC (DEG)	DELTA PI (DEG)	DELTA ASC NODE (DEG)	DELTA INCL (DEG)	DELTA L (DEG)	DELTA A (AU)
1	-0.0094	0.8309	-1.8152	-0.0115	-1.2119	-1.243E-11
2	-0.0192	1.6620	-3.6427	-0.0220	-2.4239	-1.082E-10
3	-0.0295	2.4933	-5.4809	-0.0313	-3.6358	-1.306E-10
4	-0.0401	3.3250	-7.3283	-0.0396	-4.8478	-9.854E-11
5	-0.0512	4.1571	-9.1833	-0.0469	-6.0597	-1.673E-10
6	-0.0626	4.9897	-11.0443	-0.0530	-7.2717	-1.797E-10
7	-0.0745	5.8228	-12.9094	-0.0580	-8.4836	-2.858E-10
8	-0.0868	6.6566	-14.7772	-0.0620	-9.6955	-3.100E-10
9	-0.0994	7.4910	-16.6459	-0.0649	-10.9075	-3.051E-10
10	-0.1124	8.3262	-18.5138	-0.0668	-12.1195	-4.815E-10
11	-0.1259	9.1622	-20.3794	-0.0676	-13.3315	-5.176E-10
12	-0.1396	9.9991	-22.2411	-0.0674	-14.5434	-7.018E-10
13	-0.1538	10.8369	-24.0974	-0.0662	-15.7554	-8.440E-10
14	-0.1683	11.6757	-25.9469	-0.0640	-16.9675	-9.034E-10
15	-0.1831	12.5155	-27.7883	-0.0608	-18.1795	-1.021E-09
16	-0.1984	13.3564	-29.6202	-0.0567	-19.3916	-1.069E-09
17	-0.2139	14.1984	-31.4416	-0.0517	-20.6035	-1.068E-09
18	-0.2298	15.0415	-33.2514	-0.0459	-21.8157	-1.146E-09
19	-0.2460	15.8859	-35.0486	-0.0392	-23.0278	-1.216E-09
20	-0.2625	16.7315	-36.8324	-0.0316	-24.2400	-1.170E-09
21	-0.2793	17.5783	-38.6020	-0.0233	-25.4521	-1.217E-09
22	-0.2964	18.4265	-40.3568	-0.0142	-26.6643	-1.285E-09
23	-0.3138	19.2760	-42.0962	-0.0044	-27.8765	-1.256E-09
24	-0.3315	20.1268	-43.8198	0.0061	-29.0888	-1.336E-09
25	-0.3495	20.9789	-45.5273	0.0172	-30.3011	-1.372E-09
26	-0.3677	21.8325	-47.2183	0.0290	-31.5134	-1.477E-09
27	-0.3862	22.6874	-48.8926	0.0413	-32.7257	-1.468E-09
28	-0.4049	23.5437	-50.5503	0.0543	-33.9381	-1.540E-09
29	-0.4240	24.4014	-52.1911	0.0678	-35.1505	-1.627E-09
30	-0.4432	25.2605	-53.8152	0.0818	-36.3629	-1.676E-09
31	-0.4627	26.1210	-55.4226	0.0962	-37.5754	-1.620E-09
32	-0.4824	26.9830	-57.0135	0.1112	-38.7879	-1.555E-09
33	-0.5023	27.8463	-58.5880	0.1266	-40.0004	-1.651E-09
34	-0.5225	28.7110	-60.1464	0.1424	-41.2130	-1.664E-09
35	-0.5428	29.5770	-61.6888	0.1585	-42.4256	-1.673E-09
36	-0.5634	30.4445	-63.2155	0.1751	-43.6383	-1.624E-09
37	-0.5842	31.3133	-64.7269	0.1920	-44.8210	-1.669E-09
38	-0.6052	32.1834	-66.2233	0.2093	-46.0637	-1.692E-09
39	-0.6264	33.0549	-67.7049	0.2269	-47.2765	-1.669E-09
40	-0.6477	33.9276	-69.1721	0.2448	-48.4893	-1.623E-09
41	-0.6693	34.8017	-70.6252	0.2630	-49.7022	-1.613E-09
42	-0.6911	35.6770	-72.0646	0.2815	-50.9151	-1.565E-09
43	-0.7130	36.5535	-73.4905	0.3003	-52.1280	-1.552E-09
44	-0.7351	37.4313	-74.9033	0.3193	-53.3410	-1.625E-09
45	-0.7574	38.3103	-76.3032	0.3386	-54.5541	-1.633E-09
46	-0.7799	39.1905	-77.6907	0.3581	-55.7672	-1.714E-09
47	-0.8026	40.0719	-79.0659	0.3779	-56.9803	-1.661E-09
48	-0.8255	40.9544	-80.4292	0.3980	-58.1935	-1.666E-09
49	-0.8485	41.8381	-81.7808	0.4183	-59.4068	-1.669E-09
50	-0.8717	42.7229	-83.1208	0.4388	-60.6201	-1.719E-09

51	-0.8951	43.6088	-84.4497	0.4595	-61.8334	-1.735E-09
52	-0.9188	44.4958	-85.7675	0.4805	-63.0469	-1.710E-09
53	-0.9425	45.3839	-87.0745	0.5017	-64.2603	-1.755E-09
54	-0.9665	46.2731	-88.3708	0.5231	-65.4738	-1.729E-09
55	-0.9907	47.1634	-89.6566	0.5447	-66.6874	-1.750E-09
56	-1.0151	48.0548	-90.9320	0.5666	-67.9010	-1.882E-09
57	-1.0397	48.9472	-92.1971	0.5887	-69.1147	-1.781E-09
58	-1.0644	49.8408	-93.4521	0.6110	-70.3285	-1.766E-09
59	-1.0894	50.7355	-94.6970	0.6335	-71.5423	-1.804E-09
60	-1.1146	51.6313	-95.9320	0.6562	-72.7561	-1.814E-09
61	-1.1400	52.5283	-97.1571	0.6792	-73.9700	-1.761E-09
62	-1.1657	53.4265	-98.3723	0.7024	-75.1840	-1.685E-09
63	-1.1915	54.3258	-99.5777	0.7257	-76.3981	-1.697E-09
64	-1.2176	55.2264	-100.7734	0.7493	-77.6122	-1.782E-09
65	-1.2439	56.1282	-101.9594	0.7731	-78.8264	-1.737E-09
66	-1.2704	57.0314	-103.1356	0.7971	-80.0406	-1.731E-09
67	-1.2972	57.9359	-104.3022	0.8213	-81.2549	-1.779E-09
68	-1.3242	58.8419	-105.4590	0.8457	-82.4693	-1.786E-09
69	-1.3514	59.7493	-106.6063	0.8703	-83.6837	-1.704E-09
70	-1.3789	60.6582	-107.7439	0.8950	-84.8982	-1.662E-09
71	-1.4066	61.5688	-108.8718	0.9200	-86.1128	-1.655E-09
72	-1.4346	62.4810	-109.9901	0.9451	-87.3275	-1.638E-09
73	-1.4629	63.3950	-111.0988	0.9704	-88.5422	-1.529E-09
74	-1.4914	64.3108	-112.1979	0.9953	-89.7570	-1.414E-09
75	-1.5201	65.2286	-113.2874	1.0214	-90.9718	-1.444E-09
76	-1.5491	66.1484	-114.3673	1.0471	-92.1868	-1.320E-09
77	-1.5784	67.0703	-115.4376	1.0730	-93.4018	-1.222E-09
78	-1.6079	67.9944	-116.4985	1.0989	-94.6169	-1.199E-09
79	-1.6376	68.9209	-117.5499	1.1250	-95.8321	-1.177E-09
80	-1.6677	69.8498	-118.5918	1.1512	-97.0473	-1.197E-09
81	-1.6979	70.7813	-119.6243	1.1774	-98.2626	-1.159E-09
82	-1.7285	71.7155	-120.6475	1.2038	-99.4780	-1.067E-09
83	-1.7593	72.6524	-121.6615	1.2302	-100.6935	-1.078E-09
84	-1.7903	73.5924	-122.6662	1.2566	-101.9091	-1.002E-09
85	-1.8216	74.5354	-123.6618	1.2831	-103.1247	-9.981E-10
86	-1.8531	75.4817	-124.6484	1.3095	-104.3404	-1.020E-09
87	-1.8849	76.4313	-125.6260	1.3360	-105.5562	-1.016E-09
88	-1.9169	77.3844	-126.5949	1.3625	-106.7721	-9.410E-10
89	-1.9491	78.3412	-127.5550	1.3889	-107.9880	-8.255E-10
90	-1.9816	79.3018	-128.5065	1.4153	-109.2041	-8.465E-10
91	-2.0143	80.2663	-129.4495	1.4417	-110.4202	-7.381E-10
92	-2.0471	81.2350	-130.3842	1.4679	-111.6364	-7.542E-10
93	-2.0802	82.2080	-131.3107	1.4941	-112.8526	-7.893E-10
94	-2.1135	83.1854	-132.2292	1.5202	-114.0690	-6.927E-10
95	-2.1470	84.1675	-133.1397	1.5462	-115.2854	-6.549E-10
96	-2.1806	85.1543	-134.0426	1.5720	-116.5020	-5.533E-10
97	-2.2145	86.1461	-134.9379	1.5976	-117.7186	-4.610E-10
98	-2.2484	87.1429	-135.8258	1.6231	-118.9352	-3.998E-10
99	-2.2826	88.1451	-136.7065	1.6485	-120.1520	-3.164E-10
100	-2.3168	89.127	-137.5802	1.6736	-121.3688	-2.920E-10

## PLANET NUMBER 1036 GANYMED

CENTURIES FROM EPOCH	DELTA ECC (DEG)	DELTA PI (DEG)	DELTA ASC NODE (DEG)	DELTA INCL (DEG)	DELTA L (DEG)	DELTA A (AU)
-1	0.3781	0.1260	2.2975	-0.6206	0.8544	2.674E-10
-2	0.7353	0.2877	4.7554	-1.2369	1.6973	5.661E-10
-3	1.0695	0.4822	7.3839	-1.8425	2.5288	7.823E-10
-4	1.3786	0.7065	10.1918	-2.4305	3.3494	6.697E-10
-5	1.6608	0.9579	13.1859	-2.9932	4.1599	1.122E-09
-6	1.9144	1.2332	16.3095	-3.5224	4.9609	1.276E-09
-7	2.1379	1.5297	19.7423	-4.0095	5.7532	1.206E-09
-8	2.3299	1.8445	23.2982	-4.4459	6.5378	1.466E-09
-9	2.4893	2.1746	27.0250	-4.8230	7.3158	1.774E-09
-10	2.6151	2.5173	30.9033	-5.1330	8.0883	1.921E-09
-11	2.7065	2.8696	34.9069	-5.3689	8.8565	2.109E-09
-12	2.7629	3.2287	39.0026	-5.5254	9.6219	2.024E-09
-13	2.7840	3.5917	43.1522	-5.5986	10.3855	2.072E-09
-14	2.7696	3.9559	47.3144	-5.5869	11.1439	1.917E-09
-15	2.7198	4.3183	51.4466	-5.4909	11.9133	1.973E-09
-16	2.6348	4.6760	55.5087	-5.3132	12.6801	1.870E-09
-17	2.5151	5.0203	59.4643	-5.0584	13.4907	2.115E-09
-18	2.3615	5.3663	63.2831	-4.7328	14.2261	2.148E-09
-19	2.1748	5.6930	66.9413	-4.3438	15.0077	2.108E-09
-20	1.9560	6.0036	70.4242	-3.8996	15.7265	2.297E-09
-21	1.7066	6.2952	73.7207	-3.4089	16.5934	2.244E-09
-22	1.4279	6.5648	76.8278	-2.8803	17.3994	1.930E-09
-23	1.1215	6.8096	79.7468	-2.3222	18.2152	2.115E-09
-24	0.7893	7.0265	82.4827	-1.7427	19.0415	2.222E-09
-25	0.4331	7.2125	85.0433	-1.1490	19.8786	2.719E-09
-26	0.0550	7.3648	87.4380	-0.5478	20.7271	2.907E-09
-27	-0.3429	7.4803	89.6775	0.0550	21.5872	3.068E-09
-28	-0.7583	7.5560	91.7727	0.6542	22.4589	2.792E-09
-29	-1.1888	7.5889	93.7349	1.2454	23.3423	2.690E-09
-30	-1.6320	7.5761	95.5749	1.8247	24.2374	2.839E-09
-31	-2.0855	7.5146	97.3031	2.3891	25.1438	2.578E-09
-32	-2.5467	7.4015	98.9293	2.9357	26.0615	2.356E-09
-33	-3.0130	7.2340	100.4628	3.4627	26.9899	2.418E-09
-34	-3.4919	7.0093	101.9122	3.9682	27.9288	1.824E-09
-35	-3.9508	6.7248	103.2893	4.4509	28.8776	1.271E-09
-36	-4.4170	6.3782	104.5894	4.9099	29.8359	1.484E-09
-37	-4.8779	5.9670	105.8313	5.3446	30.8031	1.864E-09
-38	-5.3309	5.4895	107.0170	5.7544	31.7786	2.399E-09
-39	-5.7735	4.9438	108.1522	6.1391	32.7620	2.860E-09
-40	-6.2031	4.3288	109.2420	6.4987	33.7527	2.930E-09
-41	-6.6173	3.6436	110.2912	6.8330	34.7000	2.930E-09
-42	-7.0134	2.8880	111.3041	7.1423	35.7532	3.031E-09
-43	-7.3993	2.0623	112.2848	7.4268	36.7625	2.434E-09
-44	-7.7424	1.1676	113.2369	7.6867	37.7767	2.917E-09
-45	-8.0707	0.2057	114.1639	7.9223	38.7953	4.304E-09
-46	-8.3719	-0.8207	115.0690	8.1338	39.8180	5.880E-09
-47	-8.6440	-1.0808	115.9553	8.3217	40.8442	7.232E-09
-48	-8.8853	-3.0517	116.8256	8.4861	41.8736	7.977E-09
-49	-9.0940	-4.2462	117.6825	8.6274	42.9055	7.579E-09
-50	-9.2687	-5.4854	118.5288	8.7458	43.9397	7.427E-09

-51	-9.4079	-6.7619	119.3468	8.8415	44.9756	7.128E-09
-52	-9.5108	-8.0677	120.1990	8.9148	46.0129	7.852E-09
-53	-9.5766	-9.3944	121.0276	8.9657	47.0511	9.923E-09
-54	-9.6045	-10.7328	121.8551	8.9244	48.0899	1.220E-08
-55	-9.5946	-12.0736	122.6438	9.0009	49.1289	1.258E-08
-56	-9.5467	-13.4075	123.158	8.9852	50.1676	1.232E-08
-57	-9.4612	-14.7251	124.3536	8.9473	51.2057	1.187E-08
-58	-9.3387	-16.0176	125.1996	8.8872	52.2427	1.198E-08
-59	-9.1801	-17.2765	126.0561	8.8047	53.2782	1.347E-08
-60	-8.9864	-18.4941	126.9257	8.6997	54.3119	1.508E-08
-61	-8.7590	-19.6634	127.8110	8.5720	55.3431	1.627E-08
-62	-8.4995	-20.7782	128.7148	8.4213	56.3716	1.688E-08
-63	-8.2096	-21.8335	129.6399	8.2476	57.3968	1.720E-08
-64	-7.8912	-22.8249	130.5896	8.0506	58.4181	1.676E-08
-65	-7.5464	-23.7491	131.5669	7.8300	59.4351	1.692E-08
-66	-7.1775	-24.6037	132.5756	7.5858	60.4473	1.736E-08
-67	-6.7867	-25.3871	133.6193	7.3176	61.4540	1.871E-08
-68	-6.3763	-26.0983	134.7021	7.0256	62.4548	1.966E-08
-69	-5.9490	-26.7373	135.8284	6.7095	63.4489	2.097E-08
-70	-5.5073	-27.3044	137.0029	6.3696	64.4358	2.176E-08
-71	-5.0536	-27.8007	138.2308	6.0061	65.4149	2.287E-08
-72	-4.5908	-28.2274	139.5176	5.6194	66.3856	2.359E-08
-73	-4.1214	-28.5863	140.3694	5.2100	67.3473	2.412E-08
-74	-3.6482	-28.8795	142.2925	4.7790	68.2994	2.417E-08
-75	-3.1739	-29.1094	143.7939	4.3273	69.2414	2.473E-08
-76	-2.7011	-29.2784	145.3811	3.8565	70.1727	2.591E-08
-77	-2.2327	-29.3892	147.0619	3.3684	71.0930	2.646E-08
-78	-1.7714	-29.4445	148.8448	2.8655	72.0019	2.736E-08
-79	-1.3197	-29.4474	150.7383	2.3506	72.8989	2.803E-08
-80	-0.8803	-29.4007	152.7514	1.8269	73.7840	2.884E-08
-81	-0.4559	-29.3075	154.8931	1.2986	74.6570	2.911E-08
-82	-0.0488	-29.1707	157.1722	0.7703	75.5180	2.950E-08
-83	0.3385	-28.9935	159.5968	0.2471	76.3669	3.008E-08
-84	0.7036	-28.7788	162.1740	-0.2649	77.2043	3.019E-08
-85	1.0444	-28.5299	164.9097	-0.7593	78.0303	3.062E-08
-86	1.3588	-28.2497	167.8070	-1.2290	78.8456	3.075E-08
-87	1.6448	-27.9414	170.8064	-1.6663	79.6559	3.122E-08
-88	1.9008	-27.6080	174.0846	-2.0637	80.4470	3.163E-08
-89	2.1251	-27.2525	177.4538	-2.4134	81.2348	3.194E-08
-90	2.3164	-26.8781	180.9611	-2.7078	82.0155	3.204E-08
-91	2.4733	-26.4877	184.5883	-2.9400	82.7903	3.223E-08
-92	2.5950	-26.0845	188.3122	-3.1042	83.5603	3.243E-08
-93	2.6806	-25.6714	192.1047	-3.1956	84.3272	3.242E-08
-94	2.7295	-25.2517	195.9344	-3.2111	85.0921	3.235E-08
-95	2.7414	-24.8282	199.7579	-3.1494	85.8268	3.201E-08
-96	2.7162	-24.4041	203.5715	-3.0110	86.6225	3.184E-03
-97	2.6540	-23.9824	207.3131	-2.7983	87.3909	3.170E-08
-98	2.5551	-23.5663	210.9638	-2.5153	88.1634	3.175E-03
-99	2.4201	-23.1589	214.4989	-2.1674	88.9414	3.219E-08
-100	2.2497	-22.7633	217.8992	-1.7612	89.7263	3.226E-08

## PLANET NUMBER 1036 GANYMED

CENTURIES FROM EPOCH	DELTA ECC (DEG)	DELTA PI (DEG)	DELTA ASC NODE (DEG)	DELTA INCL (DEG)	DELTA L (DEG)	DELTA A (AU)
1	-0.3969	-0.0873	-2.1481	0.5194	-0.8663	-3.855E-11
2	-0.8102	-0.1331	-4.1580	1.2328	-1.7446	-2.111E-10
3	-1.2376	-0.1345	-6.0405	1.8359	-2.6349	-4.998E-10
4	-1.6765	-0.0886	-7.8065	2.4254	-3.5370	-7.560E-10
5	-2.1246	0.0074	-9.4659	2.9982	-4.4508	-1.219E-09
6	-2.5791	0.1563	-11.0283	3.5521	-5.3759	-1.960E-09
7	-3.0375	0.3606	-12.5025	4.0850	-6.3121	-2.346E-09
8	-3.4973	0.6229	-13.8968	4.5955	-7.2589	-3.148E-09
9	-3.9558	0.9455	-15.2186	5.0825	-8.2159	-3.745E-09
10	-4.4104	1.3306	-16.4750	5.5451	-9.1825	-4.908E-09
11	-4.8584	1.7801	-17.6722	5.9827	-10.1582	-5.621E-09
12	-5.2974	2.2956	-18.8161	6.3950	-11.1425	-6.590E-09
13	-5.7248	2.8783	-19.9121	6.7818	-12.1348	-7.587E-09
14	-6.1380	3.5290	-20.9650	7.1431	-13.1346	-8.943E-09
15	-6.5346	4.2480	-21.9794	7.4789	-14.1413	-1.043E-08
16	-6.9122	5.0350	-22.9594	7.7894	-15.1544	-1.100E-08
17	-7.2696	5.8891	-23.9088	8.0174	-16.1733	-1.163E-08
18	-7.6014	6.8087	-24.8312	8.3356	-17.1974	-1.199E-08
19	-7.9086	7.7913	-25.7298	8.5718	-18.2264	-1.208E-08
20	-8.1882	8.8337	-26.6077	8.7838	-19.2597	-1.269E-08
21	-8.4383	9.9318	-27.4679	9.9720	-20.2969	-1.382E-08
22	-8.6572	11.0805	-28.3130	9.1367	-21.3374	-1.487E-08
23	-8.8435	12.2740	-29.1456	9.2781	-22.3809	-1.595E-08
24	-8.9959	13.5057	-29.9682	9.3965	-23.4269	-1.709E-08
25	-9.1132	14.7682	-30.7832	9.4922	-24.4751	-1.772E-08
26	-9.1947	16.0537	-31.5928	9.5653	-25.5250	-1.798E-08
27	-9.2398	17.3536	-32.3994	9.6159	-26.5762	-1.845E-08
28	-9.2481	18.6592	-33.2050	9.6442	-27.6284	-1.974E-08
29	-9.2198	19.9617	-34.0120	9.6502	-28.6812	-2.068E-08
30	-9.1549	21.2523	-34.8225	9.6341	-29.7343	-2.190E-08
31	-9.0540	22.5224	-35.6387	9.5956	-30.7872	-2.294E-08
32	-8.9179	23.7641	-36.4630	9.5349	-31.8396	-2.361E-08
33	-8.7475	24.9696	-37.2975	9.4518	-32.8910	-2.446E-08
34	-8.5441	26.1321	-38.1448	9.3461	-33.9412	-2.467E-08
35	-8.3092	27.2455	-39.0072	9.2178	-34.9897	-2.511E-08
36	-8.0443	28.3046	-39.8875	9.0667	-36.0362	-2.601E-08
37	-7.7512	29.3050	-40.7882	8.93925	-37.0800	-2.666E-08
38	-7.4320	30.2431	-41.7124	8.6951	-38.1210	-2.682E-08
39	-7.0886	31.1163	-42.6631	8.4743	-39.1535	-2.733E-08
40	-6.7233	31.9227	-43.6434	8.2300	-40.1921	-2.761E-08
41	-6.3382	32.6610	-44.6571	7.9620	-41.2213	-2.796E-08
42	-5.9358	33.3309	-45.7077	7.6704	-42.2457	-2.755E-08
43	-5.5185	33.9324	-46.7393	7.3550	-43.2648	-2.811E-08
44	-5.0886	34.4662	-47.9362	7.0161	-44.2779	-2.843E-08
45	-4.6487	34.9333	-49.1232	6.6539	-45.2848	-2.847E-08
46	-4.2014	35.3353	-50.3652	6.2687	-46.2848	-2.927E-08
47	-3.7491	35.6738	-51.6675	5.3613	-47.2174	-2.920E-08
48	-3.2943	35.9511	-53.0361	5.4324	-48.2622	-2.958E-08
49	-2.8398	36.1693	-54.4770	4.9830	-49.2388	-2.939E-08
50	-2.3879	36.3310	-55.9969	4.5147	-50.2067	-2.929E-08

51	-1.9413	36.4386	-57.6027	4.0291	-51.1657	-2.902E-08
52	-1.5025	36.4949	-59.3018	-1.283	-52.1153	-2.897E-08
53	-1.0738	36.5027	-61.1018	3.0150	-53.0553	-2.926E-08
54	-0.6577	36.4649	-63.0105	2.4922	-53.9857	-2.902E-08
55	-0.2566	36.3842	-65.0357	1.9634	-54.9063	-2.903E-08
56	0.1272	36.2636	-67.1851	1.4328	-55.8171	-2.893E-08
57	0.4916	36.1060	-69.4659	0.9050	-56.7182	-2.865E-08
58	0.8344	35.9144	-71.8847	0.3852	-57.6098	-2.851E-08
59	1.1538	35.6917	-74.4465	-0.1207	-58.4923	-2.849E-08
60	1.4478	35.4408	-77.1550	-0.6067	-59.3661	-2.825E-08
61	1.7147	35.1648	-80.0113	-1.0661	-60.2316	-2.829E-08
62	1.9530	34.8665	-83.0137	-1.4920	-61.0896	-2.833E-08
63	2.1613	34.5490	-86.1570	-1.8777	-61.9408	-2.850E-08
64	2.3383	34.2151	-89.4321	-2.2162	-62.7859	-2.821E-08
65	2.4831	33.8678	-92.8252	-2.5014	-63.6259	-2.842E-08
66	2.5947	33.5100	-96.3185	-2.7276	-64.4618	-2.836E-08
67	2.6726	33.1447	-99.8898	-2.8901	-65.2946	-2.874E-08
68	2.7162	32.7747	-103.5134	-2.9854	-66.1255	-2.871E-08
69	2.7254	32.4030	-107.1614	-3.0115	-66.9554	-2.871E-08
70	2.7000	32.0326	-110.8045	-2.9679	-67.7855	-2.861E-08
71	2.6403	31.6663	-114.4135	-2.8556	-68.6171	-2.880E-08
72	2.5466	31.3071	-117.9612	-2.6773	-69.4511	-2.882E-08
73	2.4194	30.9578	-121.4229	-2.4367	-70.2886	-2.892E-08
74	2.2597	30.6215	-124.7780	-2.1389	-71.1307	-2.920E-08
75	2.0682	30.3010	-128.0098	-1.7899	-71.9783	-2.951E-08
76	1.89463	29.9992	-131.1064	-1.3962	-72.8323	-2.946E-08
77	1.5951	29.7192	-134.0597	-0.9644	-73.6935	-3.006E-08
78	1.3163	29.4637	-136.8660	-0.5016	-74.9625	-3.049E-08
79	1.0114	29.2358	-139.5244	-0.0144	-75.4401	-3.120E-08
80	0.6822	29.0384	-142.0371	0.4907	-76.3267	-3.198E-08
81	0.3307	28.8743	-144.4082	1.0076	-77.2226	-3.256E-08
82	-0.0410	28.7465	-146.6434	1.5308	-78.1283	-3.297E-08
83	-0.4308	28.6580	-148.7494	2.0553	-79.0437	-3.292E-08
84	-0.8365	28.6115	-150.7338	2.5767	-79.9691	-3.335E-08
85	-1.2557	28.6099	-152.6041	3.0909	-80.9044	-3.346E-08
86	-1.6861	28.6561	-154.3683	3.5948	-81.8494	-3.381E-08
87	-2.1251	28.7527	-156.0342	4.0854	-82.8041	-3.447E-08
88	-2.5702	28.9024	-157.6092	4.5602	-83.7682	-3.517E-08
89	-3.0190	29.1078	-159.1006	5.0174	-84.7412	-3.575E-08
90	-3.4689	29.3713	-160.5152	5.4552	-85.7230	-3.592E-08
91	-3.9173	29.6952	-161.8596	5.8724	-86.7131	-3.653E-08
92	-4.3616	30.0815	-163.1397	6.2680	-87.7110	-3.710E-08
93	-4.7993	30.5319	-164.3612	6.6413	-88.7162	-3.757E-08
94	-5.2280	31.0480	-165.5294	6.9916	-89.7284	-3.781E-08
95	-5.6449	31.6309	-166.6492	7.3188	-90.7469	-3.868E-08
96	-6.0478	32.2813	-167.7252	7.6224	-91.7714	-3.999E-08
97	-6.4342	32.9992	-168.7615	7.9025	-92.8012	-4.063E-08
98	-6.8016	33.7843	-169.7721	8.1590	-93.8360	-4.220E-08
99	-7.1480	34.6356	-170.7307	8.3920	-94.8752	-4.268E-08
100	-7.4709	35.5513	-171.6707	8.6016	-95.9184	-4.297E-08

## PLANET NUMBER 1373 1935 ON

CENTURIES FROM EPOCH	DELTA ECC (DEG)	DELTA PI (DEG)	DELTA ASC NODE (DEG)	DELTA INCL (DEG)	DELTA L (DEG)	DELTA A (AU)
-1	0.1849	2.0659	1.3024	-0.0766	0.0903	4.930E-08
-2	0.3851	4.1156	2.6147	-0.1611	0.1772	1.063E-07
-3	0.6002	6.1486	3.9381	-0.2537	0.2602	1.661E-07
-4	0.8298	8.1644	5.2736	-0.3545	0.3391	2.230E-07
-5	1.0734	10.1629	6.6224	-0.4638	0.4134	2.695E-07
-6	1.3305	12.1438	7.9855	-0.5818	0.4827	3.022E-07
-7	1.6007	14.1073	9.3643	-0.7088	0.5465	3.145E-07
-8	1.8833	16.0535	10.7601	-0.8443	0.6043	3.032E-07
-9	2.1777	17.9826	12.1742	-0.9902	0.6557	2.657E-07
-10	2.4834	19.8951	13.6079	-1.1451	0.7001	2.035E-07
-11	2.7996	21.7913	15.0629	-1.3097	0.7370	1.156E-07
-12	3.1255	23.6719	16.5406	-1.4842	0.7657	3.557E-09
-13	3.4605	25.5375	18.0428	-1.6687	0.7856	-1.300E-07
-14	3.8036	27.3888	19.5710	-1.8633	0.7962	-2.814E-07
-15	4.1541	29.2265	21.1270	-2.0682	0.7966	-4.471E-07
-16	4.5110	31.0912	22.7129	-2.2832	0.7863	-6.239E-07
-17	4.8731	32.8639	24.3503	-2.5085	0.7644	-2.676E-07
-18	5.2387	34.6645	25.9311	-2.7432	0.7283	6.088E-06
-19	5.6066	36.4539	27.6672	-2.9872	0.6770	1.752E-05
-20	5.9758	38.2331	29.3906	-3.2402	0.6103	3.209E-05
-21	6.3452	40.0028	31.1534	-3.5019	0.5276	4.827E-05
-22	6.7140	41.7640	32.9579	-3.7720	0.4288	6.495E-05
-23	7.0810	43.5175	34.8063	-4.0497	0.3134	8.132E-05
-24	7.4451	45.2640	36.7008	-4.3347	0.1811	9.685E-05
-25	7.8053	47.0042	38.6437	-4.6259	0.0317	1.112E-04
-26	8.1603	48.7389	40.6373	-4.9227	-0.1351	1.243E-04
-27	8.5092	50.4686	42.6839	-5.2239	-0.3193	1.360E-04
-28	8.8506	52.1939	44.7855	-5.5284	-0.5210	1.463E-04
-29	9.1835	53.9154	46.9442	-5.8348	-0.7404	1.552E-04
-30	9.5066	55.6336	49.1621	-6.1416	-0.9773	1.628E-04
-31	9.8189	57.3490	51.4407	-6.4472	-1.2315	1.690E-04
-32	10.1192	59.0620	53.7815	-6.7499	-1.5028	1.736E-04
-33	10.4063	60.7730	56.1858	-7.0476	-1.7908	1.764E-04
-34	10.6792	62.4823	58.6542	-7.3383	-2.0953	1.771E-04
-35	10.9360	64.1898	61.1860	-7.6190	-2.4173	1.771E-04
-36	11.1753	65.8954	63.7801	-7.8870	-2.7570	1.770E-04
-37	11.3961	67.5993	66.4350	-8.1397	-3.1139	1.770E-04
-38	11.5975	69.3019	69.1483	-8.3748	-3.4870	1.770E-04
-39	11.7785	71.0033	71.9169	-8.5897	-3.8755	1.768E-04
-40	11.9384	72.7038	74.7369	-8.7820	-4.2782	1.769E-04
-41	12.0765	74.4036	77.6034	-8.9496	-4.6939	1.769E-04
-42	12.1922	76.1031	80.5108	-9.0904	-5.1213	1.769E-04
-43	12.2850	77.8025	83.4527	-9.2027	-5.5589	1.769E-04
-44	12.3545	79.5020	86.4220	-9.2849	-6.0052	1.769E-04
-45	12.4004	81.2020	89.4109	-9.3360	-6.4585	1.769E-04
-46	12.4225	82.9028	92.4115	-9.3551	-6.9171	1.769E-04
-47	12.4207	84.6046	95.4155	-9.3419	-7.3794	1.769E-04
-48	12.3249	86.3079	98.4143	-9.2963	-7.8435	1.769E-04
-49	12.3453	88.0129	101.3998	-9.2188	-8.3077	1.769E-04
-50	12.2721	89.7200	104.2640	-9.1101	-8.7702	1.769E-04

-51	12.1755	91.4296	107.2993	-8.9715	-9.2292	1.769E-04
-52	12.0560	93.1419	110.1988	-8.8045	-9.6831	1.769E-04
-53	11.9140	94.8575	113.0564	-8.6107	-10.1301	1.769E-04
-54	11.7501	96.5166	115.8666	-8.3923	-10.5628	1.769E-04
-55	11.5651	98.2996	118.6248	-8.1515	-10.9977	1.769E-04
-56	11.3595	100.0269	121.3272	-7.8906	-11.4153	1.769E-04
-57	11.1344	101.7589	123.9711	-7.6122	-11.8203	1.769E-04
-58	10.8906	103.4961	126.5542	-7.3187	-12.2118	1.769E-04
-59	10.6291	105.2388	129.0753	-7.0126	-12.5885	1.769E-04
-60	10.3509	106.9875	131.5337	-6.6963	-12.9497	1.769E-04
-61	10.0573	108.7426	133.9293	-6.3724	-13.2946	1.769E-04
-62	9.7493	110.5047	136.2625	-6.0430	-13.6226	1.769E-04
-63	9.4282	112.2741	138.5344	-5.7104	-13.9332	1.769E-04
-64	9.0952	114.0516	140.7463	-5.3765	-14.2261	1.769E-04
-65	8.7517	115.8375	142.8996	-5.0433	-14.5011	1.769E-04
-66	8.3991	117.6325	144.9963	-4.7124	-14.7580	1.769E-04
-67	8.0385	119.4372	147.0385	-4.3834	-14.9969	1.768E-04
-68	7.6715	121.2524	149.0282	-4.0637	-15.2180	1.768E-04
-69	7.2994	123.0786	150.9677	-3.7485	-15.4215	1.768E-04
-70	6.9234	124.9167	152.8573	-3.4409	-15.6077	1.768E-04
-71	6.5451	126.7674	154.7054	-3.1417	-15.7760	1.768E-04
-72	6.1657	128.6315	156.5083	-2.8517	-15.9293	1.767E-04
-73	5.7864	130.5098	158.2702	-2.5717	-16.0667	1.767E-04
-74	5.4087	132.4031	159.9933	-2.3021	-16.1883	1.767E-04
-75	5.0337	134.3124	161.6800	-2.0433	-16.2951	1.768E-04
-76	4.6627	136.2385	163.3323	-1.7957	-16.3878	1.768E-04
-77	4.2968	138.1822	164.9523	-1.5594	-16.4671	1.768E-04
-78	3.9372	140.1443	166.5420	-1.3347	-16.5336	1.769E-04
-79	3.5850	142.1256	168.1032	-1.1215	-16.5879	1.770E-04
-80	3.2411	144.1269	169.6378	-0.9200	-16.6308	1.771E-04
-81	2.9066	146.1488	171.1477	-0.7300	-16.6630	1.772E-04
-82	2.5825	148.1918	172.6343	-0.5516	-16.6850	1.773E-04
-83	2.2696	150.2564	174.0995	-0.3845	-16.6975	1.774E-04
-84	1.9688	152.3431	175.5446	-0.2287	-16.7012	1.775E-04
-85	1.6809	154.4519	176.9713	-0.0840	-16.6966	1.776E-04
-86	1.4067	156.5830	178.3808	0.0497	-16.6844	1.777E-04
-87	1.1469	158.7361	179.7745	0.1726	-16.6651	1.778E-04
-88	0.9021	160.9111	181.1537	0.2852	-16.6392	1.778E-04
-89	0.6730	163.1073	182.5197	0.3874	-16.6074	1.778E-04
-90	0.4601	165.3241	183.8737	0.4793	-16.5700	1.778E-04
-91	0.2640	167.5606	185.2167	0.5613	-16.5277	1.778E-04
-92	0.0851	169.8154	186.5498	0.6335	-16.4808	1.777E-04
-93	-0.0761	172.0874	187.8743	0.6961	-16.4299	1.777E-04
-94	-0.2193	174.3748	189.1909	0.7492	-16.3752	1.776E-04
-95	-0.3441	176.6759	190.5009	0.7931	-16.3174	1.776E-04
-96	-0.4502	178.9886	191.8050	0.8277	-16.2567	1.775E-04
-97	-0.5375	181.3109	193.1044	0.8534	-16.1936	1.775E-04
-98	-0.6056	183.6404	194.3998	0.8701	-16.1285	1.775E-04
-99	-0.6246	185.9748	195.6923	0.8779	-16.0616	1.775E-04
-100	-0.6844	188.3114	196.9827	0.8770	-15.9935	1.775E-04

## PLANET NUMBER 1373 1935 QN

CENTURIES FROM EPOCH	DELTA ECC (DEG)	DELTA PI (DEG)	DELTA ASC NODE (DEG)	DELTA INCL (DEG)	DELTA L (DEG)	DELTA A (AU)
1	-0.1693	-2.0813	-1.2934	0.0689	-0.0934	-3.791E-08
2	-0.3227	-4.1771	-2.5788	0.1303	-0.1895	-6.187E-08
3	-0.4598	-6.2865	-3.8571	0.1842	-0.2881	-7.208E-08
4	-0.5804	-8.4081	-5.1293	0.2310	-0.3888	-6.901E-08
5	-0.6844	-10.5408	-6.3962	0.2705	-0.4914	-5.503E-08
6	-0.7714	-12.6829	-7.6587	0.3031	-0.5956	-3.413E-08
7	-0.8415	-14.8330	-8.9177	0.3288	-0.7011	-1.037E-08
8	-0.8943	-16.9893	-10.1740	0.3475	-0.8077	1.246E-08
9	-0.9299	-19.1502	-11.4283	0.3595	-0.9150	2.927E-08
10	-0.9482	-21.3138	-12.6816	0.3647	-1.0230	3.955E-08
11	-0.9492	-23.4782	-13.9347	0.3631	-1.1313	4.132E-08
12	-0.9328	-25.6417	-15.1882	0.3548	-1.2396	3.437E-08
13	-0.8991	-27.8023	-16.4432	0.3397	-1.3478	1.912E-08
14	-0.8482	-29.9584	-17.7004	0.3178	-1.4555	-1.432E-09
15	-0.7802	-32.1081	-18.9605	0.2890	-1.5626	-2.303E-08
16	-0.6952	-34.2499	-20.2245	0.2533	-1.6687	-4.302E-08
17	-0.5934	-36.3822	-21.4932	0.2106	-1.7736	-5.680E-08
18	-0.4750	-38.5035	-22.7675	0.1607	-1.8771	-6.084E-08
19	-0.3402	-40.6125	-24.0483	0.1035	-1.9787	-5.077E-08
20	-0.1893	-42.7082	-25.3365	0.0389	-2.0783	-2.611E-08
21	-0.0225	-44.7895	-26.6330	-0.0333	-2.1755	1.296E-08
22	0.1597	-46.8555	-27.9388	-0.1132	-2.2700	6.587E-08
23	0.3571	-48.9057	-29.2549	-0.2010	-2.3614	1.298E-07
24	0.5693	-50.9394	-30.5825	-0.2969	-2.4494	1.984E-07
25	0.7958	-52.9564	-31.9225	-0.4012	-2.5335	2.652E-07
26	1.0361	-54.9264	-33.2761	-0.5140	-2.6133	3.273E-07
27	1.2899	-56.9393	-34.6445	-0.6356	-2.6884	3.762E-07
28	1.5565	-58.9052	-36.0290	-0.7661	-2.7583	4.071E-07
29	1.8354	-60.8344	-37.4309	-0.9059	-2.8226	4.143E-07
30	2.1260	-62.7872	-38.8515	-1.0551	-2.8306	3.964E-07
31	2.4277	-64.7039	-40.2922	-1.2139	-2.9318	3.485E-07
32	2.7397	-66.6052	-41.7546	-1.3825	-2.9757	2.722E-07
33	3.0613	-68.4915	-43.2402	-1.5612	-3.0116	1.672E-07
34	3.3917	-70.3636	-44.7507	-1.7500	-3.0388	3.492E-08
35	3.7302	-72.2222	-46.2878	-1.9490	-3.0567	-1.209E-07
36	4.0754	-74.0676	-47.8532	-2.1582	-3.0638	3.747E-06
37	4.4251	-75.8998	-49.4482	-2.3770	-3.0568	2.248E-05
38	4.7785	-77.7197	-51.0747	-2.6051	-3.0351	5.342E-05
39	5.1347	-79.5283	-52.7345	-2.8425	-2.9983	9.346E-05
40	5.4927	-81.3265	-54.4296	-3.0891	-2.9458	1.400E-04
41	5.8516	-83.1154	-56.1620	-3.3446	-2.8773	1.909E-04
42	6.2104	-84.8959	-57.9338	-3.6088	-2.7923	2.445E-04
43	6.5681	-86.6687	-59.7470	-3.8811	-2.6904	2.995E-04
44	6.9236	-88.4348	-61.6037	-4.1610	-2.5712	3.550E-04
45	7.2759	-90.1949	-63.5062	-4.4480	-2.4344	4.102E-04
46	7.6240	-91.9496	-65.4565	-4.7412	-2.2796	4.647E-04
47	7.9666	-93.6998	-67.4567	-5.0398	-2.1065	5.131E-04
48	8.3028	-95.4459	-69.5090	-5.3427	-1.9151	5.701E-04
49	8.6313	-97.1887	-71.6154	-5.6488	-1.7050	6.206E-04
50	8.9510	-98.9286	-73.7777	-5.9568	-1.4763	6.694E-04

51	9.2609	-100.6661	-75.9976	-6.2652	-1.2289	7.163E-04
52	9.5598	-102.4018	-78.2767	-6.5724	-0.9630	7.608E-04
53	9.8466	-104.1359	-80.5162	-6.8768	-0.6783	8.028E-04
54	10.1203	-105.8690	-83.0170	-7.1763	-0.3765	8.415E-04
55	10.3799	-107.6015	-85.4798	-7.4692	-0.0565	8.765E-04
56	10.6243	-109.3335	-88.0046	-7.7532	0.2807	9.069E-04
57	10.8526	-111.0656	-90.5110	-8.0262	0.6344	9.320E-04
58	11.0639	-112.7980	-93.2381	-8.2960	1.0039	9.507E-04
59	11.2574	-114.5309	-95.9442	-8.5304	1.3884	9.622E-04
60	11.4322	-116.2648	-98.7069	-9.7570	1.7870	9.656E-04
61	11.5868	-117.9989	-101.5217	-8.9628	2.2005	9.656E-04
62	11.7200	-119.7331	-104.3831	-9.1449	2.6290	9.656E-04
63	11.8313	-121.4676	-107.2859	-9.3014	3.0711	9.656E-04
64	11.9202	-123.2027	-110.2237	-9.4304	3.5254	9.656E-04
65	11.9864	-124.9396	-113.1898	-9.5305	3.9904	9.656E-04
66	12.0297	-126.6759	-116.1767	-9.6005	4.4546	9.656E-04
67	12.0499	-128.4146	-119.1768	-9.6395	4.9462	9.656E-04
68	12.0469	-130.1553	-122.1819	-9.6472	5.4336	9.656E-04
69	12.0209	-131.8993	-125.1838	-9.6235	5.9249	9.626E-04
70	11.9719	-133.6440	-128.1746	-9.5686	6.4184	9.656E-04
71	11.9004	-135.3928	-131.1464	-9.4834	6.9123	9.656E-04
72	11.8065	-137.1452	-134.0919	-9.3687	7.4048	9.656E-04
73	11.6909	-138.9015	-137.0042	-9.2260	7.8942	9.656E-04
74	11.5539	-140.6622	-139.8773	-9.0569	8.3788	9.656E-04
75	11.3964	-142.4278	-142.7058	-8.8634	8.8571	9.656E-04
76	11.2188	-144.1998	-145.4849	-8.6474	9.3274	9.656E-04
77	11.0222	-145.9755	-148.2110	-8.4111	9.7883	9.656E-04
78	10.8073	-147.7586	-150.8311	-8.1570	10.2385	9.656E-04
79	10.5750	-149.5486	-153.4930	-7.8873	10.6763	9.656E-04
80	10.3264	-151.3458	-156.0452	-7.6044	11.1020	9.656E-04
81	10.0626	-153.1508	-158.5369	-7.3107	11.5132	9.656E-04
82	9.7846	-154.9642	-160.9680	-7.0084	11.9095	9.656E-04
83	9.4937	-156.7866	-163.3387	-6.6997	12.2903	9.656E-04
84	9.1910	-158.6183	-165.6499	-6.3868	12.6549	9.656E-04
85	8.8778	-160.4601	-167.9027	-6.0715	13.0029	9.656E-04
86	8.5554	-162.3125	-170.0987	-5.7557	13.3339	9.656E-04
87	8.2250	-164.1761	-172.2374	-5.4411	13.6477	9.656E-04
88	7.8881	-166.0515	-174.3269	-5.1291	13.9443	9.626E-04
89	7.5464	-167.9393	-176.3627	-4.8218	14.2250	9.739E-04
90	7.2019	-169.8400	-178.3489	-4.5208	14.4914	9.970E-04
91	6.8560	-171.7540	-180.2876	-4.2273	14.7437	1.026E-03
92	6.5099	-173.6817	-192.1814	-3.9422	14.9322	1.057E-03
93	6.1647	-175.6240	-184.0328	-3.6658	15.2064	1.090E-03
94	5.8213	-177.5816	-185.8445	-3.3982	15.4165	1.126E-03
95	5.4807	-179.5552	-187.6189	-3.1406	15.6122	1.166E-03
96	5.1439	-181.5455	-189.3582	-2.8923	15.7936	1.210E-03
97	4.8122	-183.5227	-191.0642	-2.6543	15.9615	1.247E-03
98	4.4866	-185.5772	-192.7390	-2.4266	16.1161	1.277E-03
99	4.1679	-187.6194	-194.3845	-2.2095	16.2576	1.297E-03
100	3.8571	-189.6797	-196.0026	-2.0024	16.3864	1.306E-03

## ENCKE'S COMET

CENTURIES FROM EPOCH	DELTA ECC (DEG)	DELTA PI (DEG)	DELTA ASC NODE (DEG)	DELTA INCL (DEG)	DELTA L (DEG)	DELTA A (AU)
-1	-0.0420	-0.4260	0.8890	0.4706	1.8341	5.403E-05
-2	-0.0808	-0.8581	1.7104	0.8847	2.6714	1.013E-04
-3	-0.1158	-1.2955	2.4813	1.2405	5.5120	1.406E-04
-4	-0.1464	-1.7378	3.2158	1.5370	7.3561	1.705E-04
-5	-0.1721	-2.1840	3.9264	1.7732	9.2039	1.902E-04
-6	-0.1927	-2.6333	4.6241	1.9485	11.0555	1.986E-04
-7	-0.2077	-3.0849	5.3193	2.0623	12.9111	1.950E-04
-8	-0.2171	-3.5378	6.0218	2.1146	14.7707	1.815E-04
-9	-0.2207	-3.9905	6.7411	2.1058	16.6324	1.789E-04
-10	-0.2186	-4.4420	7.4971	2.0363	18.4963	1.885E-04
-11	-0.2110	-4.8915	8.2706	1.9067	20.3624	2.093E-04
-12	-0.1979	-5.3381	9.1033	1.7179	22.2310	2.403E-04
-13	-0.1799	-5.7809	9.9983	1.4708	24.1024	2.805E-04
-14	-0.1573	-6.2192	10.9708	1.1670	25.9766	3.288E-04
-15	-0.1306	-6.6523	12.0387	0.8082	27.8540	3.843E-04
-16	-0.1005	-7.0797	13.2233	0.3965	29.7347	4.459E-04
-17	-0.0675	-7.5008	14.5505	-0.0654	31.6190	5.125E-04
-18	-0.0324	-7.9154	16.0523	-0.5742	33.5071	5.834E-04
-19	0.0042	-8.3231	17.7688	-1.1259	35.3992	6.574E-04
-20	0.0414	-8.7240	19.7505	-1.7157	37.2955	7.338E-04
-21	0.0784	-9.1179	22.0617	-2.3374	39.1961	8.119E-04
-22	0.1145	-9.5052	24.7851	-2.9833	41.1012	8.908E-04
-23	0.1490	-9.8860	28.0270	-3.6439	43.0110	9.700E-04
-24	0.1811	-10.2608	31.9227	-4.3066	44.9255	1.049E-03
-25	0.2101	-10.6301	36.6401	-4.9556	46.8447	1.127E-03
-26	0.2354	-10.9946	42.3762	-5.5700	48.7689	1.205E-03
-27	0.2665	-11.3550	49.3328	-6.1230	50.6978	1.281E-03
-28	0.2728	-11.7122	57.6540	-6.5819	52.6317	1.356E-03
-29	0.2840	-12.0671	67.3107	-6.9098	54.5703	1.430E-03
-30	0.2898	-12.4207	77.9695	-7.0724	56.5136	1.504E-03
-31	0.2899	-12.7740	88.9689	-7.0488	58.4615	1.577E-03
-32	0.2844	-13.1280	99.5155	-6.8396	60.4138	1.650E-03
-33	0.2733	-13.4838	108.9882	-6.4666	62.3704	1.723E-03
-34	0.2567	-13.8423	117.1031	-5.9637	64.3311	1.799E-03
-35	0.2349	-14.2046	123.8646	-5.3668	66.2956	1.876E-03
-36	0.2081	-14.5715	129.4319	-4.7076	68.2636	1.957E-03
-37	0.1770	-14.9440	134.0062	-4.0121	70.2351	2.042E-03
-38	0.1420	-15.3226	137.7836	-3.3006	72.2095	2.132E-03
-39	0.1037	-15.7080	140.9267	-2.5890	74.1868	2.228E-03
-40	0.0629	-16.1009	143.5663	-1.8898	76.1666	2.331E-03
-41	0.0202	-16.5014	145.8046	-1.2129	78.1486	2.441E-03
-42	-0.0236	-16.9098	147.7211	-0.5664	80.1320	2.555E-03
-43	-0.0678	-17.3260	149.3777	0.0431	82.1161	2.669E-03
-44	-0.1114	-17.7502	150.8234	0.6105	84.1011	2.784E-03
-45	-0.1538	-18.1820	152.0972	1.1313	86.0869	2.905E-03
-46	-0.1941	-18.6213	153.2300	1.6022	88.0735	3.032E-03
-47	-0.2317	-19.0676	154.2469	2.0201	90.0610	3.168E-03
-48	-0.2658	-19.5205	155.1687	2.3829	92.0496	3.315E-03
-49	-0.2960	-19.9793	156.0123	2.6885	94.0393	3.475E-03
-50	-0.3216	-20.4433	156.7924	2.9355	96.0303	3.649E-03

-51	-0.3422	-20.9118	157.5213	3.1226	98.0228	3.839E-03
-52	-0.3575	-21.3838	158.2101	3.2490	100.0168	4.044E-03
-53	-0.3672	-21.8584	158.8686	3.3140	102.0125	4.265E-03
-54	-0.3713	-22.3347	159.5056	3.3169	104.0095	4.495E-03
-55	-0.3697	-22.8115	160.1298	3.2577	106.0075	4.731E-03
-56	-0.3625	-23.2879	160.7497	3.1363	108.0067	4.972E-03
-57	-0.3499	-23.7630	161.3736	2.9530	110.0073	5.218E-03
-58	-0.3321	-24.2360	162.0107	2.7083	112.0095	5.467E-03
-59	-0.3097	-24.7060	162.6704	2.4029	114.0135	5.719E-03
-60	-0.2830	-25.1723	163.3633	2.0380	116.0195	5.974E-03
-61	-0.2526	-25.6342	164.1017	1.6147	118.0278	6.231E-03
-62	-0.2192	-26.0912	164.8997	1.1346	120.0385	6.489E-03
-63	-0.1833	-26.5429	165.7747	0.5999	122.0519	6.749E-03
-64	-0.1459	-26.9889	166.7478	0.0129	124.0682	7.009E-03
-65	-0.1076	-27.4290	167.8458	-0.6235	126.0976	7.271E-03
-66	-0.0692	-27.8633	169.1032	-1.3059	128.1103	7.534E-03
-67	-0.0315	-28.2916	170.5655	-2.0299	130.1365	7.797E-03
-68	0.0047	-28.7144	172.2942	-2.7906	132.1664	8.062E-03
-69	0.0386	-29.1318	174.3739	-3.5818	134.2001	8.328E-03
-70	0.0696	-29.5444	176.9245	-4.3956	136.2377	8.595E-03
-71	0.0969	-29.9527	180.1194	-5.2223	138.2794	8.864E-03
-72	0.1201	-30.3575	184.2147	-6.0482	140.3252	9.136E-03
-73	0.1385	-30.7592	189.5916	-6.8544	142.3747	9.406E-03
-74	0.1517	-31.1587	196.8075	-7.6125	144.4266	9.662E-03
-75	0.1593	-31.5567	206.6049	-8.2794	146.4807	9.902E-03
-76	0.1612	-31.9542	219.6882	-8.7911	148.5370	1.013E-02
-77	0.1573	-32.3521	235.9278	-9.0682	150.5953	1.034E-02
-78	0.1476	-32.7515	253.3806	-9.0520	152.6556	1.053E-02
-79	0.1322	-33.1532	269.1313	-8.7526	154.7180	1.071E-02
-80	0.1115	-33.5582	281.5866	-8.2414	156.7822	1.088E-02
-81	0.0857	-33.9673	290.8581	-7.5990	158.8484	1.103E-02
-82	0.0555	-34.3814	297.6959	-6.8861	160.9164	1.117E-02
-83	0.0212	-34.8010	302.8145	-6.1427	162.9863	1.131E-02
-84	-0.0163	-35.2269	306.7359	-5.3946	165.0581	1.143E-02
-85	-0.0565	-35.6574	309.8144	-4.6588	167.1318	1.155E-02
-86	-0.0985	-36.0989	312.2883	-3.9475	169.2073	1.167E-02
-87	-0.1415	-36.5457	314.3196	-3.2693	171.2848	1.178E-02
-88	-0.1848	-36.9997	316.0210	-2.6309	173.3643	1.189E-02
-89	-0.2275	-37.4611	317.4727	-2.0375	175.4459	1.200E-02
-90	-0.2688	-37.9295	318.7335	-1.4931	177.5296	1.212E-02
-91	-0.3079	-38.4046	319.8470	-1.0012	179.6155	1.224E-02
-92	-0.3441	-38.8861	320.8471	-0.5642	181.7039	1.236E-02
-93	-0.3768	-39.3733	321.7601	-0.1843	183.7947	1.250E-02
-94	-0.4052	-39.8656	322.6077	0.1368	185.8881	1.264E-02
-95	-0.4289	-40.3623	323.4077	0.3978	187.9843	1.278E-02
-96	-0.4473	-40.8624	324.1755	0.5976	190.0835	1.294E-02
-97	-0.4603	-41.3652	324.9248	0.7357	192.1858	1.311E-02
-98	-0.4675	-41.8697	325.6683	0.8115	194.2914	1.328E-02
-99	-0.4689	-42.3749	326.4183	0.8248	196.4005	1.347E-02
-100	-0.4641	-42.8798	327.1870	0.7757	198.5133	1.366E-02

## ENCKE'S COMET

CENTURIALS FROM EPOCH	DELTA_LCC (DEG)	DELTA_PI (DEG)	DELTA_ASC_NODE (DEG)	DELTA_INCL (DEG)	DELTA_L (DEG)	DELTA_A (AU)
1	0.0446	0.4195	-0.9772	-0.5253	-1.8310	-5.941E-05
2	0.0910	0.8321	-2.0685	-1.1029	-3.6592	-1.228E-04
3	0.1385	1.2375	-3.3075	-1.7299	-5.4845	-1.889E-04
4	0.1863	1.6356	-4.7382	-2.4029	-7.3071	-2.564E-04
5	0.2336	2.0264	-6.4205	-3.1174	-9.1271	-3.239E-04
6	0.2797	2.4100	-8.4375	-3.8682	-10.9446	-3.904E-04
7	0.3239	2.7866	-10.9083	-4.6484	-12.7596	-4.549E-04
8	0.3654	3.1567	-14.0080	-5.4490	-14.5722	-5.163E-04
9	0.4035	3.5206	-18.0007	-6.2578	-16.3824	-5.741E-04
10	0.4378	3.8789	-23.2938	-7.0569	-18.1902	-6.274E-04
11	0.4676	4.2324	-30.5124	-7.8184	-19.9957	-6.759E-04
12	0.4926	4.5817	-40.5540	-8.4972	-21.7987	-7.190E-04
13	0.5124	4.9277	-54.3887	-9.0242	-23.5993	-7.566E-04
14	0.5267	5.2713	-72.0503	-9.3014	-25.3975	-7.885E-04
15	0.5355	5.6133	-91.1353	-9.2538	-27.1932	-8.147E-04
16	0.5386	5.9547	-107.9411	-8.8924	-28.9864	-8.351E-04
17	0.5362	6.2964	-120.7421	-8.3033	-30.7769	-8.500E-04
18	0.5283	6.6392	-129.9666	-7.5767	-32.5649	-8.596E-04
19	0.5154	6.9841	-136.6184	-6.7760	-34.3501	-8.641E-04
20	0.4978	7.3317	-141.5274	-5.9407	-36.1325	-8.640E-04
21	0.4759	7.6829	-145.2557	-5.0956	-37.9122	-8.597E-04
22	0.4502	8.0383	-148.1676	-4.2573	-39.6890	-8.518E-04
23	0.4214	8.3983	-150.5006	-3.4373	-41.4628	-8.408E-04
24	0.3902	8.7635	-152.4127	-2.6443	-43.2338	-8.275E-04
25	0.3571	9.1341	-154.0123	-1.8852	-45.0019	-8.125E-04
26	0.3231	9.5104	-155.3752	-1.1654	-46.7670	-7.966E-04
27	0.2888	9.8924	-156.5567	-0.4893	-48.5291	-7.807E-04
28	0.2549	10.2800	-157.5973	0.1393	-50.2884	-7.656E-04
29	0.2223	10.6731	-158.5279	0.7174	-52.0447	-7.523E-04
30	0.1916	11.0714	-159.3726	1.2424	-53.7983	-7.415E-04
31	0.1636	11.4744	-160.1504	1.7122	-55.5491	-7.342E-04
32	0.1388	11.8817	-160.8769	2.1250	-57.2973	-7.313E-04
33	0.1178	12.2926	-161.5650	2.4795	-59.0429	-7.333E-04
34	0.1011	12.7065	-162.2260	2.7745	-60.7860	-7.411E-04
35	0.0892	13.1226	-162.8694	3.0093	-62.5268	-7.552E-04
36	0.0824	13.5400	-163.5044	3.1831	-64.2654	-7.760E-04
37	0.0809	13.9580	-164.1393	3.2957	-66.0019	-8.039E-04
38	0.0848	14.3755	-164.7821	3.3470	-67.7365	-8.391E-04
39	0.0942	14.7917	-165.4410	3.3368	-69.4693	-8.814E-04
40	0.1090	15.2058	-166.1243	3.2656	-71.2005	-9.308E-04
41	0.1292	15.6167	-166.8410	3.1338	-72.9302	-9.869E-04
42	0.1543	16.0237	-167.6008	2.9421	-74.6587	-1.049E-03
43	0.1842	16.4260	-168.4146	2.6915	-76.3859	-1.118E-03
44	0.2182	16.8228	-169.2947	2.3833	-78.1121	-1.191E-03
45	0.2561	17.2136	-170.2558	2.0190	-79.8373	-1.269E-03
46	0.2971	17.5976	-171.3148	1.6006	-81.5617	-1.350E-03
47	0.3407	17.9746	-172.4924	1.1304	-83.2854	-1.435E-03
48	0.3861	18.3440	-173.8137	0.6114	-85.0085	-1.521E-03
49	0.4328	18.7058	-175.3097	0.0471	-86.7310	-1.608E-03
50	0.4798	19.0597	-177.0192	-0.5582	-88.4529	-1.697E-03

51	0.5266	19.4059	-178.9910	-1.1993	-90.1744	-1.785E-03
52	0.5723	19.7443	-181.2874	-1.8699	-91.8953	-1.872E-03
53	0.6163	20.0754	-183.9880	-2.5620	-93.6157	-1.959E-03
54	0.6579	20.3995	-187.1949	-3.2650	-95.3355	-2.043E-03
55	0.6903	20.7170	-191.0377	-3.9689	-97.0547	-2.126E-03
56	0.7312	21.0287	-195.6775	-4.6554	-98.7732	-2.207E-03
57	0.7618	21.3352	-201.3031	-5.3048	-100.4908	-2.285E-03
58	0.7879	21.6373	-208.1101	-5.8913	-102.2076	-2.361E-03
59	0.8090	21.9359	-216.2445	-6.3831	-103.9232	-2.434E-03
60	0.8249	22.2319	-225.6972	-6.7445	-105.6377	-2.504E-03
61	0.8334	22.5263	-236.1775	-6.9422	-107.3508	-2.572E-03
62	0.8405	22.8201	-247.0753	-6.9547	-109.0624	-2.637E-03
63	0.8401	23.1142	-257.6237	-6.7815	-110.7722	-2.700E-03
64	0.8346	23.4097	-267.1583	-6.4429	-112.4802	-2.760E-03
65	0.8239	23.7075	-275.4482	-5.9724	-114.1862	-2.817E-03
66	0.8086	24.0034	-282.3736	-5.4059	-115.8899	-2.872E-03
67	0.7891	24.3132	-288.1014	-4.7760	-117.5913	-2.925E-03
68	0.7657	24.6228	-292.8257	-4.1091	-119.2902	-2.976E-03
69	0.7391	24.9373	-296.7372	-3.4261	-120.9863	-3.025E-03
70	0.7099	25.2586	-299.9998	-2.7431	-122.6798	-3.072E-03
71	0.6788	25.5950	-302.7459	-2.0728	-124.3703	-3.117E-03
72	0.6465	25.9195	-305.0799	-1.4249	-126.0578	-3.162E-03
73	0.6137	26.2601	-307.0833	-0.8075	-127.7423	-3.205E-03
74	0.5811	26.6074	-308.8128	-0.2268	-129.4237	-3.248E-03
75	0.5494	26.9615	-310.3392	0.3120	-131.1020	-3.291E-03
76	0.5199	27.3222	-311.6812	0.6047	-132.7772	-3.335E-03
77	0.4918	27.6890	-312.8774	1.2478	-134.4493	-3.380E-03
78	0.4672	28.0617	-313.9534	1.6385	-136.1183	-3.425E-03
79	0.4461	28.4337	-314.9303	1.9746	-137.7843	-3.473E-03
80	0.4290	28.8222	-315.8255	2.2540	-139.4473	-3.524E-03
81	0.4165	29.2033	-316.6536	2.4753	-141.1075	-3.577E-03
82	0.4088	29.5985	-317.4276	2.6372	-142.7650	-3.633E-03
83	0.4062	29.9905	-318.1583	2.7389	-144.4199	-3.693E-03
84	0.4040	30.3841	-318.8558	2.7797	-146.0722	-3.757E-03
85	0.4171	30.7783	-319.5294	2.7590	-147.7222	-3.824E-03
86	0.4305	31.1723	-320.1875	2.6766	-149.3701	-3.895E-03
87	0.4493	31.5651	-320.8388	2.5325	-151.0158	-3.969E-03
88	0.4730	31.9560	-321.4917	2.3268	-152.6597	-4.047E-03
89	0.5015	32.3440	-322.1553	2.0599	-154.3018	-4.128E-03
90	0.5344	32.7285	-322.8393	1.7324	-155.9424	-4.212E-03
91	0.5712	33.1088	-323.5544	1.3451	-157.5815	-4.298E-03
92	0.6114	33.4842	-324.3133	0.8992	-159.2192	-4.385E-03
93	0.6543	33.8541	-325.1309	0.3959	-160.8558	-4.474E-03
94	0.6994	34.2182	-326.0256	-0.1628	-162.4914	-4.565E-03
95	0.7459	34.5761	-327.0206	-0.7748	-164.1260	-4.655E-03
96	0.7932	34.9276	-328.1450	-1.4374	-165.7597	-4.746E-03
97	0.8405	35.2726	-329.4414	-2.1475	-167.3927	-4.837E-03
98	0.8870	35.6111	-330.9615	-2.9010	-169.0250	-4.927E-03
99	0.9322	35.9432	-332.7831	-3.6931	-170.6567	-5.016E-03
100	0.9751	36.2692	-335.0175	-4.5176	-172.2878	-5.105E-03